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THE FUTURE OF ELECTRICITY IN RAILROAD WORK.*

BY DR. LOUIS DUNCAN.

In a paper read some time ago, I discussed the application of electricity to steam railroad practice, and attempted to define the relations of existing steam railroads to the recent developments in electric traction, and in it all I found no great present hope for the steam roads. The fact exists that there is but a small margin of profit in railroading, and with innumerable electric roads paralleling their steam rivals and absorbing their local traffic, the margin promises to be still smaller. One naturally asks why, if the trolley is less expensive and gives a better service than steam, do not the steam roads adopt the trolley; but it must be remembered that besides local service, the trunk roads have through passengers and freight to transport, and that the

* A lecture delivered before the Franklin Institute, January 17, 1896.

three types of traffic cannot be successfully operated on the same tracks, especially if we attempt a really efficient local and express schedule.

The question that wants clearing up is this: Is our present method of transportation, as a whole, the result of the characteristics of the steam locomotives that are employed, or is it a natural system which is not greatly affected by the particular tractive power used?

In the United States, the freight traffic is two or three times greater in gross value than the passenger traffic, and, on the whole, it pays much better. A glance at the annual report of any railroad company will also show that, from the point of view of a railroad man, it is a more satisfactory type of traffic. In the first place, the trains being long and running at a comparatively low speed, the resistance per ton is small as compared with passenger trains, which are relatively shorter and run at high speeds. In the second place, the ratio of the paying weight to the total weight of the train is much greater in freight than in passenger service. In an annual report of the Pennsylvania Railroad I find that the average load of freight cars, for several years, is about half the total weight of the train. In passenger service, on the other hand, even on well-patronised roads, the ratio of train weight to weight of passengers is over 50 to 1, and if we take the average conditions, I imagine that 60 or 70 to 1 would not be far wrong.

In freight transportation, where the time is, within limits, of little value, it is easy to calculate what speed will give the best results; that is, what speed will allow us to transport a given tonnage at the least cost. But in passenger traffic the condition of affairs is different, and, with the competition now existing, it is a question not only of cheap transportation, but of quick and comfortable transportation. There is absolutely no doubt that the high speeds used on some of the express trains between New York and Chicago, for instance, or between New York and Washington, are exceedingly expensive. More power is used—for the resistance of the train increases rapidly at the high speeds employed—the wear is increased, both of the train and the

track, and expensive and heavy cars are used to give comfortable riding. And yet the railroads are still reducing their schedule time, simply because the public will patronise the road with the fastest service.

With the present steam system, the condition with the three types of service—express, local and freight—is this: express trains are run at comparatively long intervals; local trains are run from or between comparatively crowded centers of population at shorter intervals; and freights are filled in between, partly on regular schedule, partly not. This condition of things fits in very well with the best conditions of economy for steam engines. For a given amount of traffic it is cheapest to use as long trains and as few engines as possible. So steam has this great advantage, that the very conditions that allow local, express and freight traffic on the same tracks also give the best conditions for economy in conducting the traffic. It is only the most crowded roads that have found it necessary to equip four tracks—the four-track roads forming but an exceedingly small percentage of the total mileage.

Now, with electric roads the condition of affairs is very different. As far as the operation of freight is concerned, I will quote what I said in the address mentioned above:

"If we take up the question of freight traffic, the conditions of greatest economy are reached when trains of a maximum weight are hauled by a single locomotive. The tendency in late years has been in the direction of increasing the size of the locomotive, the capacity of the cars and the length of the trains. These changes have necessitated more solid and expensive road-beds, heavier rails and general strengthening of bridges. The outlay has been enormous, but the decreased cost per ton mile for freight transportation has shown the wisdom of the change. On one of the larger roads, which publishes careful yearly statistics, I find that the cost of transportation per ton mile was 1·15 cents in 1870, and ·56 cent in 1890; on another road it was 1·9 cents in 1864, and ·447 cent in 1893. The number of tons per train mile on the first road in 1870 was 103, while in 1890 it was 226 (in 1895 it was 256 tons). In attempting to

carry on traffic of this kind by electrical locomotives operated from a central station, we find that we are at a great disadvantage because of the irregular service necessitated by the freight traffic, and the unequal distribution of the load along the line. Suppose, for instance, that there were two stations supplying the line, and that the traffic was uniformly distributed along it; then the capacity of each station would be one-half of the total required capacity. Suppose, however, that the entire traffic was concentrated in one train, then each station would have to have a capacity equal to the total power required for hauling the entire traffic, as the train would first be supplied from one station and then from the other. The line also would have to have a capacity suitable for handling the total traffic. If a number of heavy trains were used, and the traffic was irregular and liable to be congested at one point, as in the case of freight service, then again the capacity of the stations would have to be greater than that required to supply one-half of the normal traffic. If we were to decide to transmit the current to a longer distance, and to supply all the track from one station, using transformer devices along the line, then the capacity of the station itself would only be that required for the normal traffic of the line; but the transformer devices would have to be sufficient to handle the maximum traffic of the section which they supplied, and would have to be given a capacity greatly in excess of their average load in order to supply this energy. We must bear distinctly in mind, in considering the application of electricity to steam roads, that any departure from a uniform distribution of load along the line will increase both the cost of equipment and the cost of operation."

If, then, we operate freight at all by electricity, we must use smaller trains, thus increasing the cost of train attendance and the number and cost of motors, or we must get some cheaper method of distribution, or, finally, we must generate the electricity on the train.

Now, if we increase the number of trains, we increase the enginemen and to some extent the brakemen, and we increase the first cost of, and repairs on, the motors. The

increase in these items will depend on the amount of subdivision we attempt. As for the methods of distribution, the only one that would not require an excessive station or transformer capacity would be a high-tension alternating system, with the transformers on the cars. This involves practical difficulties which have not yet been even attacked. As we decrease the size of trains, we decrease the cost of station and line equipment and operation, and increase the cost of train-handling.

As for any self-contained locomotives, we must either use storage batteries, which at present are out of the question, or must have a central station on trucks, as in the case of the Heilman locomotive, which was experimented on in France. We can neglect these either in the present or in the near future.

An ideal local service would consist of a system owning the tracks in the different towns it connects, with cars running through and between the towns. This would give termini measured in square miles instead of square feet, and, with a clear, well-built track, would present an ideal condition of service.

As for ordinary express service, here also, as for local traffic, electricity offers ideal conditions. Trains of one or two cars may be run at short intervals and at high speeds, the conditions of greatest electrical economy and of most satisfactory service being the same. It has often been pointed out that electrical economy demands short intervals and small trains, and, by properly arranging the schedule, the load on the stations may be made practically uniform. It must be taken into account, however, that if we are running trains at, say, 90 miles an hour on a twenty-minute headway, the trains will be 30 miles apart, and at the distances used at present in railroad distribution we would have to provide a larger amount of copper on our lines, that would be used only a short portion of the time.

As for the speeds that may be attained, it is hard to fix a limit. We can get enough power on the train to make 120, or even 150 miles an hour possible, and the small space occupied, as compared with steam engines, would make the

air resistance comparatively much less. But we have increased our air resistance per ton by splitting up our trains, and as we increase our speed we greatly increase the power required to drive our train over the line. Still, in passenger service it is not economy solely that sets our speed limit, and I suppose it will finally be limited by the safety and comfort of the passengers. With a perfect road-bed of the present type, and with properly designed motors and cars, 100 miles an hour may be made with comfort and safety.

So much for our electrical service. Its economy for freight is very questionable, and the only advantages it offers are in the smaller trains which are easier to handle and which offer less chance of accident. For local traffic it is ideal. For express traffic it is also ideal within distances of a few hundred miles.

But what are the conditions under which we can carry on this traffic? We certainly cannot run our express trains with either the freights or locals. We would have then to build separate express tracks, and, in order to get the service we have contemplated, they would have to be of the most expensive construction, with no grade crossings or sharp curves. As for running freights and locals on the same track, this may be done under certain conditions.

If we regulate our local service by running it on a regular tramway basis in the towns, and making few if any stops between them, then we may run freights and locals on the same through tracks. But under these conditions we cannot run as the ordinary trolley cars run, stopping at every crossing, because the freights do not stop at all, and their speed is as high as we can comfortably run the light car we would choose for economical town work. It must be remembered, too, that when our local cars are on the same tracks with the comparatively heavy freights, which cannot easily be braked, we cannot take liberties with our schedule; it is too dangerous. If our road has a heavy freight traffic, and we divide the present freight trains into several lighter trains, the tracks will be quite full without the locals, and convenience and safety would point to separate tracks for each.

The above brief survey brings us to the following conclusions: the present custom of using comparatively heavy trains at long intervals is the result of two things—it gives the maximum economy for steam locomotives, and it requires the minimum investment in tracks. If we attempt to accomplish the same service by electricity, we must build at least one extra pair of tracks for express work, and the roads which would require four tracks, because of heavy freight traffic, must increase to six to accommodate the local service. To replace steam by electricity means a greater investment in tracks; it means, with our present prices and methods of distribution, a greater investment in motive power; it promises a cheaper and more satisfactory local and express service, while the freight service may or may not be cheaper, depending on local conditions.

In the paper to which I have referred, I pointed out what I considered the relation of the present steam roads to electricity, taking things as they actually are. I will now consider things as I believe they will or may be, in the not very far distant future. In the first place, local traffic (and I use the word in its popularly-understood sense, not the local traffic of railroad reports) must soon be absorbed by electric lines. The reason is very plain. It is cheaper to transport passengers for short distances by trolley than by steam cars, and the service is much more satisfactory. The ratio of weight of passengers to dead weight is much greater in electric than in steam transportation, and the motive power is cheaper. Cars may be taken almost anywhere and at almost any time, and, for the greater part of the year, it is more pleasant to ride in trolley cars than on a steam road. Besides the ordinary type of local traffic, there is no doubt that populous sections of the country will be networked with electric roads, and that the greater part of the transportation of local freight from outlying districts into cities and towns will be done by electricity. The great advantage of electricity lies in the fact that it does not require skilled labor to run the cars, the machinery—especially if rotary field motors are used—being of ideal simplicity, and requiring very little expense in the way of repairs. Light

tracks may be used and the roads will require little grading; for with light traffic it does not pay to increase the permanent investment too much, in order to save running expenses. Every such road should, in fact, represent a special problem, in which the increased running expense for a more expensive road-bed should be balanced against first cost. That such a system is inside the limit of prophecy is shown by the following quotation from a late impression of the New York *Evening Post:*

"Five long suburban electric railways are now in operation, radiating from Cleveland, or will be by early summer. The Cleveland and Painesville line unites this city with the seat of Lake County, and is about 23 miles in length from the eastern city limits. The Akron, Bedford and Cleveland Road has its termini, respectively, in Akron, Summit County, and at the southerly limits of Cleveland, a distance of more than 30 miles. The Cleveland and Berea Company is operating from the southwesterly city limits to Berea, having about 9 miles of single track, exclusive of switches and turn-outs. The Cleveland-Elyria road has just been completed, and extends from the western limits of Cleveland to Elyria, the seat of Lorain County, a distance of over 20 miles; while the Lorain and Cleveland line, which will be ready for traffic in the early summer, connects Lorain, the growing lake port and steel manufacturing town on the lake shore, west of this city, with the westerly limits of Cleveland, and will have about 22 miles of track, exclusive of switches and turn-outs. At present, these lines end at the limits of the city, and depend upon the city electric lines to bring their passengers to the center of the city. No freight has been carried thus far, except small packages. The expectation is, however, to handle a large amount of farm produce in baskets, boxes and barrels, as soon as the proper terminals can be secured in this city. The cars are as large as ordinary railroad coaches, and are combination cars, having apartments for package freight and baggage, as well as passengers.

"Within two weeks, these lines, which are controlled by a syndicate of local capitalists, headed by Mr. Henry A.

Everett, of this city, have united to apply for franchises for 85 miles of road in the streets of this city. They propose to operate these city lines, in conjunction with their suburban roads, as a single great system, and to use the city streets, between the hours of midnight and 5.30 A.M., to bring in milk, fruit and country produce of all sorts. They propose to secure a fine site in the center of the city and erect a large terminal station for the handling of freight, as well as for the accommodation of suburban passengers. This is the first step. Later, as the freight traffic increases, it is expected to construct small freight stations in different sections of the city along the lines of road, in order to supply every section with produce with as little handling and at as small an expense as possible. The roads are all incorporated under the steam railroad laws, and expect to condemn property to connect streets that are not now cut through, thus securing more direct routes than would otherwise be possible; practically, all direct streets radiating from the center of the city being occupied by existing street railroads.

"In order to create a public opinion in favor of this new and radical scheme, the new company offers to give universal transfers, so that a passenger can ride over the whole road for one fare if he desires to, and to sell eight tickets for 25 cents, good for transfers, all hours of the day and night. As the lines they have projected will parallel many now being operated by the two consolidated street railway companies here, the latter have begun a bitter fight, the result of which is difficult to predict. Should the new lines be able to secure the franchise they seek from the city, the old street railway companies threaten to cut their rates of fare to 3 cents, and inaugurate a 'war,' the outcome of which, to all the railway interests involved, could hardly fail to be disastrous.

"The great question involved in the entire matter, however, is the proposed use of the streets, on a large scale, by electric traction companies for carrying freight. If the plans outlined are put in practice, there is a very strong prospect that the new company will undertake to haul

freight from one quarter of the city to another, as well as to handle produce and package freight from the suburban districts. Many large manufacturing establishments are directly along the proposed routes, and interchanges of products between many of them are frequent, and involve heavy expense for cartage. The projectors of the new lines believe that, within a few years, they will be able to do much of this business at a saving to the manufacturers, and still realise a good profit on the business. Meanwhile, the great question is the wisdom of allowing a company of this character the unrestricted use of the streets during certain hours, and the ultimate effects of the plan if it is carried out, as it will be, unless the existing street railway companies succeed in defeating the project in the City Council. The general opinion seems to be that the innovation would reduce the cost of placing fruit and farm produce in the hands of the city consumer, and thus be a public benefit, and it is already demonstrated that the electric lines can compete with steam very successfully. The Akron, Bedford and Cleveland Company has been operating cars between Akron and Cleveland less than four months, but it has already made such inroads into the business of the steam railroads, that the Cleveland, Akron and Columbus Railroad Company has laid off two of its way trains between these points, and the outlook is for the development of a good business by the new company. Its time is somewhat longer than that of the steam roads; but the freedom from dust, cinders and similar annoyances of the steam road, and the greater frequency of trains—cars being run on a forty-five minute schedule—seem fully to offset this objection."

With the methods of distribution in common use, such a system could be run for a radius of 10 miles from a single station, and in the next two or three years we may hope to extend our radius at least 20 miles. The agitation for good country roads that is now being carried on may be too late, for, by the time it is really decided to build them, we may have reached an era of electric lines and bicycle paths rendering them unnecessary.

FREIGHT AND EXPRESS FEEDERS.

Express traffic by electricity demands a large investment, a considerable running expense, and a distinct advance over our present methods of electric traction. We can look for revenue only to passenger traffic, with some additional receipts from express and mail. If we take the receipts on steam railroads as a basis, we will find that there are few such express lines that will pay. But we must take into account the great increase in passenger traffic that would follow the quicker service and shorter intervals that would be employed. No one can doubt that, if the time from Philadelphia to New York could be reduced to one hour, and if trains ran every fifteen or twenty minutes, the number of passengers between these two points would be greatly increased. The number of schemes that have been proposed for lines running from Philadelphia, and even from Washington, to New York, shows that the matter is in the air, and is being seriously considered by responsible people. There is nothing "wildcat" about the matter, but one must not blind himself to the practical difficulties that will be encountered. As far as the present steam roads are concerned, it is doubtful whether the increased earnings that would follow the building and equipment of such an electric road would pay them for the great expense of it. They would be driven to it only if an independent line threatened to destroy their through passenger traffic between these points. The existing roads, with their rights of way and terminal facilities already secured, could establish such a service at a much less expense than any independent company. To build a line from Washington to New York, against the opposition of the steam roads operating between these points, would require great ability and shrewdness on the part of the officials of the company, and an enormous outlay of money. No one who has not looked into the subject can imagine the difficulties and expense incident to securing terminal facilities in the different towns; and the cost and trouble in securing rights of way—always considerable—can be greatly increased by the organised and intelligent opposition of companies backed by enormous wealth and

influence, and with an experience extending from the introduction of railroads.

Of our ability to run trains at speeds up to 100 miles an hour I have already spoken. Our experience is this: the speed of ordinary trolley cars has been gradually increased in suburban service, until, in certain cases, speeds up to 40 miles an hour are employed. More than this, on the Columbia and Maryland Railroad, which is now being built between Baltimore and Washington, speeds of 60 miles are to be used. In the past year, trains on the Nantasket Beach branch of the New York and New Hampshire Road have been run at speeds above 60 miles, and similar results have been obtained on the Mt. Holly branch of the Pennsylvania Road. In the last two cases, the cars used were not specially constructed for very high speeds, and yet there seemed to be no trouble in operating them. Some of the difficulties that have been feared have proved to be imaginary; some have been overcome; and I suppose that the same will be the case when we attempt the greater velocities demanded by an electric express system. Some years ago, it was supposed that the increase in train resistance at very high speeds would render them prohibitive; but some of the recent runs on steam roads, together with actual experiments made on electric cars at speeds up to 120 miles an hour, have shown that the formulæ that were assumed to be true were wrong, all of them giving too great resistance at high speeds. The work done on resistance by Mr. Crosby is especially interesting. He experimented in two ways. First, he ran a small electric car on a circular track and measured the velocity and the power consumed. From these data, knowing the constants of the motors, he was able to obtain the total resistance at the different speeds used. But he went further than this. He made the front end of the car movable, working in guides against the calibrated spring, and, by getting a record of the movement of the end on a revolving cylinder by a pencil, he obtained the air resistance. Subtracting this from the total, the remainder was the track resistance. These experiments were repeated with heads of different forms, and the effect of the

shape on the resistance was determined. The results were checked by placing a model in a rotating frame, and finding the air resistance at different velocities. The results of Mr. Crosby's work showed that speeds as high as 120 or 150 miles could be made without increasing the power to an impossible (?) amount, provided we make the train of a proper shape. The form of our electric machinery allows us to dispose our weights near the track, and so allow higher speeds to be safely used than could be allowed with the present type of equipment. The rotary motion of the armatures is much more advantageous than the reciprocating motion of the piston, and the wear on track and bridges would be much less.

Up to the present, rotary field alternating motors have been used only experimentally, but the experiments have been most promising, and the characteristics of the machines fit singularly well the requirements of the traffic we have been considering. Such motors are most efficient for the constant speeds, while their construction and regulation are of ideal simplicity. Besides this, the multiphase alternating system is peculiarly adapted to long-distance transmission. The great plant at Niagara, which is in successful operation, and from which it is proposed to transmit power over long-distances, is a multiphase plant. The system allows us to use any voltage we wish on the line, and the problem which has not yet been attacked—the collecting of the current at these speeds—is helped by this fact.

The first road that will, to a certain extent, fulfill the conditions of an electric express road is now being built between Baltimore and Washington, and its operation will solve many of the questions which come up, in the higher speed work we are considering—questions such as the type of car that may be used, the mounting of the motors, etc.

It is only between crowded centers of population that such roads can be made to pay. Between Washington and New York, New York and Boston, and possibly between New York and Chicago, they might be constructed at present; but, as the distances increase, the demand for the comforts of trains like our "Chicago Limited" work against our

condition of light trains. On long trips we are accustomed to dining and sleeping cars, to observation and smoking cars, and we cannot provide all these on our electric train run at 100 or 120 miles an hour. Still, we might combine enough of these comforts in a single train to make an eight- or nine-hour trip to Chicago not unpleasant, and that is the greatest distance I have in mind as a requirement of the immediate future.

As for the safety of such a service, it should be greater than with our present system. With a perfectly clear track for our express trains, with lighter weights allowing quicker braking, with simple machinery that permits a low center of gravity, with less strain on our road-bed due to the rotary motion employed, with a perfect track construction and the definite block system that electricity permits, the service should be absolutely safe. The comfort of the passengers would depend on the construction of the track and of the cars. We know that we can build a smooth track, and we may depend on the ingenuity of our car builders to give us smooth-riding cars.

Such a system offers us a service at once frequent, rapid, comfortable and safe, surpassing the present steam service in each of these particulars, and there is no problem involved which our present knowledge of electric traction and transmission will not enable us to solve successfully.

But the local and express services on the lines I have sketched out would be entirely different. They could not be operated on the same tracks, the types of cars and motors would not be the same; even the methods of distribution would, in all probability, vary. The local service, extending in every direction that offers a profitable passenger or freight traffic, would employ a cheap and comparatively light road-bed, open passenger cars for summer and the ordinary closed cars for winter use. The express trains would be vestibuled, the cars presenting a smooth surface, and the locomotives designed to give the least possible air resistance. The tracks would be heavily built, straight, with no grade crossings—more expensive even than the present steam roadway. On steam roads, one cannot at a

glance distinguish between local and express trains. The types, both of locomotives and cars are similar, the fact that both services use the same tracks demanding powerful locomotives for both services. Where the stops are numerous, the power required to accelerate the heavy trains used demands locomotives as heavy as those which give the sustained power for the express trains. We can, and, often do, change cars from locals to express trains, and but for minor differences in design, we could use our locomotives indiscriminately for either service. In our electrical system, the difference between locals and express would be obvious. We could not use either our local cars or motors for express service, and our express trains would be hardly more at home on local tracks.

As for freight service, I own that my ideas on the subject are not as clear as I could wish. The remarkable efficiency and cheapness of the present system make the problem of improvement a difficult one. As I have said before, the present methods of distribution demand shorter trains, and there is nothing I can see in the immediate future that promises to change this condition. With our electric trains we have some very important advantages, such as less fuel, cheaper switching, cheaper engineers, less repairs on engines and cars, smaller cost of maintenance of way. Against these items we have the increased cost of service due to the smaller train units employed. In any case, whether we use steam or electricity, our freight lines would be through lines. From points along them electric roads would radiate, draining the surrounding country and feeding the main line. Most of the trunk lines in the country have been forced to build or buy branch lines to act as feeders, and these branches rarely pay their operating expenses. Electricity will, in many cases, change this, and will both decrease the expenses and increase the traffic on the branch roads, and so directly benefit the main stem.

The invention and development of the steam engine led to the concentration of industries. The maximum economy is reached in the use of large units, of great factories of concentrated effort. This has had its evil side, socially, mor-

ally and often industrially. Electricity lends itself to the distribution of power, to the economical use of small units, and we are already beginning to feel its effect. In many cases it puts the small manufacturer nearer the level of the larger corporation; it is to-day distributing the crowded population of great cities to the surrounding suburbs. Its moral and social effects are far-reaching and wholesome, tending, as they do, toward greater individuality with its accompanying greater independence.

And to a certain extent this is true with respect to electric railroads. The substitution of electricity for steam demands small units, and it sharply differentiates the three types of traffic, local, express and freight. Local roads will network the country, carrying passengers and freight to cities and towns, or to through freight and express roads. Express lines will be built between large cities, the equipment of track and trains differing radically from that for local service, and speeds of from 100 to 120 miles will be attained with comfort and safety. The freight service proper will be done on through tracks fed from local lines, the type of equipment differing widely from that for either local or express service.

I have not considered how all this is going to come about. It means, of course, a radical change not only in the system of motive power, but also in the roadway of some 200,000 miles of railroad. The cost of it would run up in the thousands of millions of dollars. But this is certain, if the transportation work of the country can be carried on more cheaply and efficiently by electricity than by steam, then it is only a question of time when electricity will be substituted. We already have an example of the future type of local traffic in the roads spoken of in the New York *Evening Post*. Express traffic has been fairly well represented by the Baltimore-Washington road. Through freight is the one doubtful point, but we regard it with the eyes of hope.

There are, I hope, but few of us here who will not see a comprehensive adoption of electricity on some of our great systems, and there are some who will live to see the time when the steam locomotive will be considered a curiosity.

THE FRANKLIN INSTITUTE.

Stated Meeting, April 15, 1896.

MR. JOS. M. WILSON, President, in the chair.

THE WORTHINGTON COOLING TOWER FOR THE CONTINUOUS USE OF CONDENSING WATER.

BY JOHN H. COOPER.

The chief object of this apparatus is to reduce the temperature of water, which has become heated in some previous operation, in order that it may be used over and over again for the same purpose. In cities, where even the feed-water for steam boilers is obtained only at considerable cost, the purchase of water for condensing purposes, requiring about twenty-five times the amount of water in the steam, is commercially impracticable, for the reason that its cost will be greater than the advantages gained.

The cooling of warm water, therefore, and re-using it for the condensation of steam in the steam engine, for increasing its power without additional fuel, or for maintaining the same power on less fuel, become matters of great commercial importance, because this use of water is almost without cost. Furthermore, as is well known, there are even disadvantages attending a natural water supply, such as the cost of piping and pumping, obstructions to pipes, valves and water passages, gritty and corrosive matters, which are detrimental to pump and pipe interiors and to working parts, and the inconveniences of floods and drought, over which we have no control.

Any invention, therefore, that removes the difficulty and cost of obtaining water for condensing purposes, in localities where natural supply does not exist, or fails at times, must have great commercial value. If it were possible to construct steam motors and run them condensing, with all the advantages secured by this system, by the use of no more water than that employed for making their steam, a great

gain would be effected in steam economy, and nothing henceforth would be in the way of locating them wherever desired. The Worthington "cooling tower" enables steam-power users to avail themselves effectually of this advantage.*

This apparatus comprises several specially designed mechanisms for cooling a certain quantity of water and using the same over and over again. It embodies the results of much experimentation, conducted for some time in the establishment of Henry R. Worthington, in Brooklyn, N. Y., by which are secured all the requirements for cooling water with continued good results, combined with durability of mechanism. Its distribution and disintegration of water, to effect intimate contact and commingling with atmospheric air, are complete, while the space occupied by the apparatus is reduced to the least amount compatible with the work to be done.

It is now offered to engineers and steam users in a practical form, as the finished result of trials in actual service in connection with several large power plants in New York City and elsewhere, after having successfully passed the ordeal of experiment.

Owing to several meritorious features, the cost of producing a vacuum by this novel system is but slightly greater than that of the ordinary condensing apparatus operated with a natural and abundant water supply. As the heat of the exhaust steam from the condenser pump is transferred to the feed-water and returned to the boiler by means of a suitable heater, it is practically all conserved. The power to operate the fan is quite insignificant, and, in fact, the total expenditure to run the Worthington "self-cooling condenser," when deducted from the great gain afforded the main engines by the vacuum, results in an economy that gives a handsome return on the investment, and places a plant equipped with it, nearly, if not fully, on a par in efficiency with the best and most recent practice of condensing engines.

* The apparatus herein referred to is manufactured by Henry R. Worthington, Brooklyn, N. Y.

An important advantage is gained in the use of this apparatus, in that no vacuum is required to be maintained in

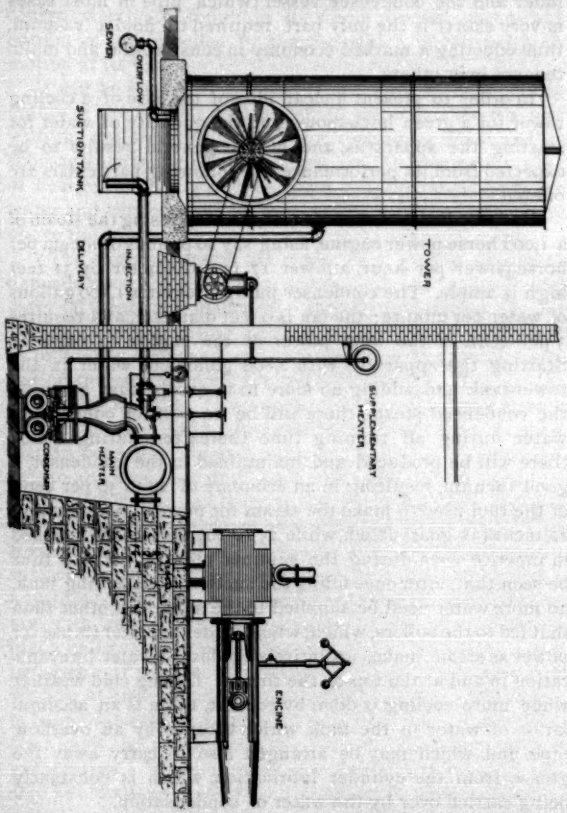


FIG. 1.—Worthington self-cooling condenser (showing tower in yard).

the tower, nor in its water connections with the condenser pump, and that the tower may be placed at any reasonable distance from the engine, as, for example, in the open air or

on the ground, or upon the roof of some adjacent building. With this system, the exhaust pipe between the steam cylinder and the condenser vessel (which pipe in most cases is very short) is the only part required to hold a vacuum, thus effecting a marked economy in construction and maintenance over others.

In order to present a clear idea of the size of a cooling tower for a given horse-power, of the quantity of water for starting the apparatus, and of the general results to be expected from its performance, the following particulars are offered:

Under ordinary circumstances, for condensing the steam of a 1,000 horse-power engine, using say 20 pounds of steam per horse-power per hour, a tower 17 feet diameter by 31 feet high is ample. The condenser pump circulates 1,500 gallons of water per minute; the fan is 9 feet diameter, and requires 3 per cent. of the total power of the engine to drive it. Starting the apparatus with 2,800 gallons of water in the tower-tank and adding no more to it, except that given by the condensed steam, there will be no cost for condensing water during all running time thereafter, during which there will be produced and maintained in the condenser, a good vacuum, resulting in an economy of 20 to 30 per cent. of the fuel used to make the steam for power. A vacuum of 22 inches is guaranteed, while 25 to 26½ inches are realised in practice even during the summer months. It will thus be seen that, after once filling the suction or subsiding tank, no more water need be supplied to the apparatus other than that fed to the boilers, which, when condensed after its use for power as steam, makes up entirely the loss of water by evaporation in and at the top of the tower. During cold weather when more cooling is done by contact, there is an accumulation of water in the tank which escapes by an overflow pipe, and which may be arranged also to carry away the grease from the cylinder lubrication, which is constantly being carried over by the water of condensation.

The condenser pump delivers the warm water to the top of the tower where it is distributed evenly over the entire area of the cellular arrangement within the same. As the

water falls through the tower, it is repeatedly divided and subdivided into drops and streams during its downward course, meeting, throughout its whole descent an upward current of air, impelled by the fan which is constantly in motion at its base.

It will be apparent, therefore, that, with the unchanging nature of the cellular devices, which are of earthen tile, and with the uniform disintegration of the falling water and its thorough contact with atmospheric air, the greatest number of heat units, within a given space, are abstracted from the water and carried away by evaporation into the atmosphere above the tower.

"The effectiveness of the tower as a cooling apparatus depends upon the capacity of atmospheric air to absorb and carry off heat and moisture. Broadly considered, the air becomes the condensing medium in the place of cold water as ordinarily employed, and on account of its general distribution the process is not limited as to locality. The specific heat of air is 0·238. If we depended upon the direct absorption of heat by rise in temperature we should have to raise about 4 pounds or about 55 cubic feet of air 1°, or 1 cubic foot 55°, to absorb a heat unit, 1,000 cubic feet 55° to condense 1 pound of steam, and from 15,000 to 20,000 cubic feet per hour to condense the steam used per horse-power hour. This would be the requirement if the air were circulated over the surface of pipes containing the steam as water is circulated in a surface condenser. But when air is brought into direct contact with water there is a cooling action due to evaporation, much more extensive than that due to the elevation of temperature. If you wet your hand and hold it in a current of air, you at once experience a sensation of cold. The water is being absorbed or evaporated by the air, and is taking from your hand and the surrounding objects the latent heat of evaporation. When a pound of water is evaporated in this way five times as much heat disappears as when a pound of water is raised from the freezing to the boiling point, and every pound of water so evaporated absorbs heat enough to condense a pound of steam. By passing, therefore, a current of air over a body of water favorably disposed to be acted

upon and absorbed by the air, we can, by the evaporation of a portion of that water, absorb and carry off in the air current a large amount of heat, and cool the water sufficiently to allow it to be used again for injection purposes. Further, for every pound of water thus carried off by the air, enough cold is generated (if the unscientific expression may be allowed) to condense a pound of steam, so that there is no diminution of water in the system, and the only water required to be supplied continuously is that fed to the boilers, *which is less, of course, than if the plant were run non-*

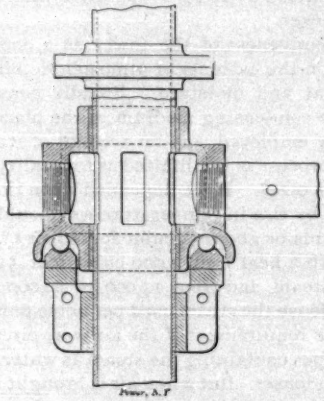


FIG. 2.—Details of revolving distributor.

condensing, on account of the reduced steam consumption of the engine. The system, therefore, allows a plant which must even buy its feed water, to run condensing with a less expense for water than when exhausting into the atmosphere.

"The details of the system are apparent from the engravings. The hot water from the condenser pump is delivered through the revolving distributor into the top of the large tank. This distributor is an interesting detail. It is necessary that the water shall be evenly distributed through the

tower section, in order that the maximum effect may be derived from a given quantity of air. Several forms of perforated plates were used as distributors, with the result that the water was forced either to the center or outside of the column and the air found clear passages. The distributing pipe is mounted at its center on ball bearings, as shown in the detail drawing, *Fig. 2*, also in plan on *Fig. 4*, and, rotating like the ordinary lawn-sprinkler under the reaction of the issuing jets, distributes the water uniformly over the cross section of the tower. The first impression is that the issuing jets would be thrown to the outside and impinge on the walls of the tower, but the actual effect is that the drops fall vertically, forming circles as they issue from the pipe, and effecting a very uniform and satisfactory distribution. The body of the tower is filled with short lengths of cylindrical tiling over which the water trickles, meeting the

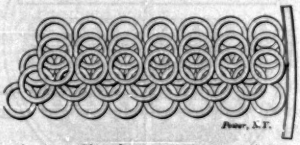


FIG. 3.—Showing arrangement of tiles.

ascending current of air induced by the fan as shown. The tiles are so arranged as to break joints (see *Fig. 3*, also *Fig. 4*), and present a generous surface over which the water spreads in a thin sheet in the best possible form to be acted upon by the air, which is passing through the interstices of the tiling, and being constantly deflected and broken up into small columns in intimate contact with the wetted surfaces. At the bottom of the tower the water collects in a tank, whence the supply for the injection is taken. Mingling in the condenser with the steam, and being heated by its condensation, it is again delivered by the pump to the cooling tower, increased in quantity by the steam which it has condensed and which is sufficient to replace that lost by evaporation. There is constantly coming into the system the water which is drawn from the city mains or other source to feed the boilers. There is constantly going out

of the system the water evaporated in the cooling tower, an amount which can no more than equal, and may be considerably less than, the steam condensed; for, in addition to the evaporation, we have the cooling effects of radiation from the surface of the tower and the connecting pipes, and the rise in temperature of the air in passing through the tower which it leaves, it is to be noted, at the hottest end, and these last processes condense steam without the loss of water.

"If, to start with, a few gallons of water be placed in the suction tank, the system will operate without attention, and

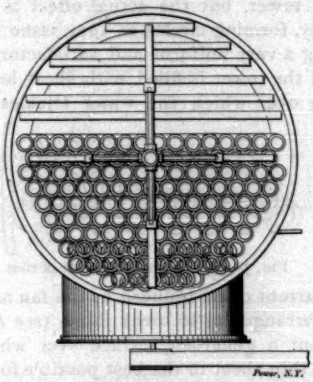


FIG. 4.—Showing plan view of tower.

all loss of water by evaporation and slight leakages will be provided for. There will be just enough accumulation of circulating water to cause a slight overflow that will carry off the oil and grease from the engine that come over with the exhaust steam, and which would tend to accumulate in the suction tank.

"In the application of this apparatus to a plant operating non-condensing, no change will be made in the method of feed-water supply, as ordinarily employed. The ordinary heater is left in position, and the exhaust steam from the engine passed through it on the way to the condenser. The

exhaust of the condenser pump and the small engine which runs the fan (if a separate engine be used) is passed through a supplementary heater and condensed by the absorption of its heat by the feed-water, which has already been heated to the temperature of the exhaust steam, say 120° to 130°, by the main heater between the engine and the condenser.

"The temperature of the feed-water, after passing the supplementary heater, will approximate 180° to 190° F. This enables the boilers to operate under specially good conditions for condensing engines.

"When the cold city water for the boiler-feed is passed through the main heater, it acts on the passing steam as in a surface condenser, reducing the work of the condenser proper and the amount of injection required. The power required to run the fan is procured very cheaply, as the heat which passes through the engine is, in great part, returned to the boilers in the feed-water.

"By the use of this system, any plant, wherever located, can secure all the benefits accruing from condensation, and with very nearly the ultimate economy attainable with a plentiful supply of condensing water. Even a plant in a city building can be run to advantage in this way, by placing the cooling tower on the roof and using a surface condenser in the basement of the building, where also the motive and other machinery is placed. The descending column of circulating water balances the ascending column, and the hydrostatic head pumped against is no greater than though the tower were upon a lower level. There will, of course, be the friction of the greater length of pipes to overcome, but this can be greatly reduced by making the pipes of sufficient size to keep the velocity down. Where the only water available is so charged with lime or other impurities as to be undesirable for boiler purposes, a surface condenser can be installed, and the condensed steam used over and over continuously in the boilers. In this case, the water lost by evaporation in the tower is made up automatically by delivering the available water to the suction tank below the cooler, as required. In no case will this be more than would be required if the engine were run non-

condensing, and the practical advantage of soft, pure feed-water is obtained in addition to the economical advantages of the condensing engine. Another practical advantage, especially in metropolitan plants, is the absence of noise and vibration, due to the exhaust and greasy discharge from the exhaust pipe.

"There is yet another important point worth noticing. The apparatus is able to maintain as high a vacuum in the summer as in the winter; for, while in hot weather it receives less help from direct radiation, or the effect of contact with cold air, the evaporation becomes a much more important factor, because the warm air is more effective in absorbing moisture, evaporation proceeds at a much greater rate, and is consequently many times more effective in cooling."

The Worthington Cooling Tower Applied to Ice-making and Refrigerating Apparatus.—The cooling tower portion of the apparatus described above has, independently, varied and important uses, the most important of which is the cooling of water that has passed over ammonia coils in connection with ice-making or refrigerating machinery, and has thereby become heated. After leaving the cooling tower the water can be used again on the coils without any further demand upon the water supply, be it from wells or the city mains, except to make up that which is lost out of the tower by evaporation. This feature will appeal to the managers of cold-storage plants and breweries as a thoroughly desirable result, especially when city water has to be purchased at great expense during the hot summer months.

Fig. 5 is taken from a photograph of a Worthington cooling tower that has been in operation during the heated term of last summer, in a cold-storage plant. The tower, as will plainly be seen, is supported over the ammonia coils upon a a light framework, and the fan is driven by a belt from the main shafting. The heated water from the coils flows to a circulating pump located in the engine-room, and it is then delivered to the top of the tower, cooled and allowed to again flow over the coils of the condenser. The application of the apparatus to this particular plant resulted in the

saving of seven-eighths of the cost of water for cooling purposes; that is, in fact, it reduced a yearly water bill of

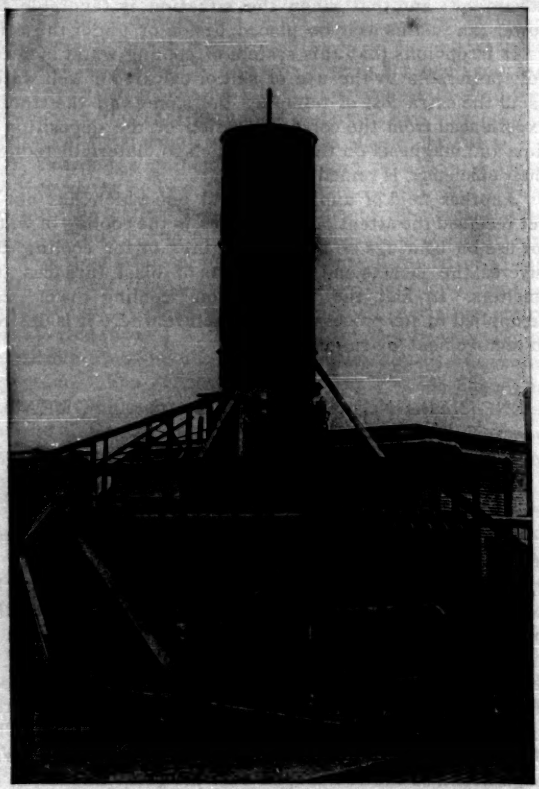


FIG. 5.—Worthington cooling tower in connection with ammonia condensers.

$4,000 to $500, thereby realising an economy that fully paid for the cooling tower in a few months.

It may be added that, when a line of shafting is not convenient, a small self-contained engine is used with equal advantage; and that, when the situation is favorable, the tower can just as well be placed beside or under the coils.

It is obvious that this system of cooling water is decidedly preferable to the use of salt or calcareous well water, as all the extra cost of pumping the same, and the trouble experienced from the corrosive action or the deposition of lime and magnesia on the coils, which so materially reduces their efficiency, is remedied.

Another field of application, and one which has not as yet received the attention it deserves, is the cooling of water for use on bearings of rolls or engines, or for cooling the tuyeres, the jackets and other parts of blast furnaces and smelters. In fact, the Worthington "cooling tower" can be applied in any process or manufacture where it is desired to remove heat by running water.

ENGINEERING AS EXHIBITED ON THE GREAT LAKES.*

By John Birkinbine,
Member of the Institute, Past President Am. I. M. E., etc.

Standing at the stern of one of the lake passenger steamers, shortly after it had started on its eastward course of 390 miles across Lake Superior, and looking back at the long array of receding electric lights, which indicated the location of Duluth and her sister city, Superior, one is impressed by the thought that less than a quarter of a century had transformed a sarcastic reference on the floor of the House of Representatives at Washington to the "Zenith City of the Unsalted Seas" into a reality. The view of these important and rapidly growing cities was magnificent, as the vessel sped over the great inland sea of Superior, whose water surface exceeds 30,000 square miles, for the illumination extended along the lake shore fully 15

* A lecture delivered before the Franklin Institute, December 6, 1895. The lecture was liberally illustrated by a large number of lantern slides.

miles, and the lights shone on the hillside to a height of 200 feet or more above the lake. Near the center of the space illumined was a concentration of brilliancy created by a raking view of numerous arc lights on an iron-ore shipping dock, one-half mile in length, and the effect as seen from the water was heightened by the two ruby lights, one fixed, the other revolving, which the Government maintains to direct vessels into the safe harbor of Superior Bay, through the narrow, artificial canal, which divides Minnesota Point.

A knowledge, gained from repeated professional visits covering parts of two decades, of how Duluth has grown, and how the entire territory tributary to the Great Lakes has advanced, credits much of this progress to the engineer; and a recapitulation of his achievements in the lake district, would, of itself, occupy an evening, while there are a number, which, if described in detail, would each merit the entire time allotted to me. With so much to choose from, works of magnitude must be slighted which may appear of greater importance than others which are mentioned; hence, no claim for completeness is presented, but an attempt will be made to illustrate the importance of the Great Lakes, and chronicle some of the advances which have contributed to their present development.

But little attention can be devoted to the lowest of the lakes, Ontario, although it has numerous important works of interest to engineers, and the lecture will merely cover some of the impressive features in journeys between Buffalo and Chicago or Duluth.

DIMENSIONS OF THE GREAT LAKES.

These bodies of water are truly "Great Lakes," and great engineering achievements are associated with them. Few realise that the bulk of the immense traffic of the Great Lakes (a traffic in volume in advance of any navigation with which we are familiar in Philadelphia) is carried on at levels of from 573 to 602 feet above tide, and that the 3,000 craft which form the lake marine west of Buffalo float at heights of from 10 feet above to 19 below the crown of the hat of the statue of William Penn on the top of the

Philadelphia City Hall. We are familiar with the expression "Great Lakes," but do not appreciate their magnitude.

If Lake Superior be superposed on Pennsylvania and adjoining States, its eastern extremity (Whitefish Bay) can be placed at Sandy Hook, N. J., and Duluth at its western end would be found beyond Wheeling, W. Va., the greatest width of the lake corresponding closely with the north and south boundaries of Pennsylvania.

If Lake Michigan be so placed that Philadelphia occupies the same relative position on its shore as Chicago, the northern end of the lake would extend to Montpelier, Vt., its width being practically the distance between the cities of Philadelphia and New York. Treating Lake Huron in a similar manner, and placing its southern extremity at Philadelphia, it would extend in a northern direction beyond Albany and Troy, N. Y., the foot of Georgian Bay corresponding with New Haven, Conn., that of Saginaw Bay being at Pottsville, Pa., while the Straits of Mackinac would approach Rochester, N. Y., the distance from the foot of the lake to the straits being practically that between Philadelphia and Pittsburgh. Assuming Philadelphia as occupying the same position on the shore of Lake Erie as Buffalo, Pittsburgh would correspond with the mouth of the Detroit River, and the distance across Lake Ontario from Watertown, N. Y., on the east, to Hamilton, Ont., on the west, is equal to that from Philadelphia to Cumberland, Md.

Starting at Duluth, a vessel of moderate size would, at present, after traversing 1,300 miles, passing *en route* the Sault Ste. Marie, the Welland and the St. Lawrence Canals, practically reach tide level at Montreal (which is 25 feet above the sea), and still be nearly 1,000 miles from the Atlantic Ocean.

Lake Superior, as above indicated, is 602 feet above tide, and is, therefore, the highest as well as the largest and deepest of the lakes: in fact, it is the largest known body of fresh water, its maximum depth being 978 feet; the bottom is nearly 400 feet below ocean level, and at ocean level its area would be between 10,000 and 15,000 square miles. But Lake Superior is not alone in this particular, for Lake Michigan

and Lake Huron, whose surfaces are 581 feet above the ocean, have maximum depths of 870 and 702 feet respectively, and Lake Ontario, 247 feet above tide, is 678 feet deep.

The waters of Lake Superior reach the level of Lakes Huron and Michigan through the St. Mary River, where about 90,000 cubic feet of water per second dash over the rapids. To overcome this difference in elevation (18 feet), locks have been constructed at the Sault Ste. Marie, in connection with a canal about 1 mile long, of which mention will be made later.

LAKE SUPERIOR.

In considering some of the prominent engineering features of Lake Superior, it is well to remember that the contiguous territory was practically an unbroken wilderness with only a few trading posts scattered along the lake shore, but little more than half a century ago. Although the discovery of mining tools in ancient workings show that the Indians had mined copper in the Keweenaw Peninsula of Michigan, and some little work was done in the latter part of the eighteenth century by whites, no mining of copper or other minerals was attempted in a business way until 1845. Now there is an enormous mining industry from which up to date 100,000,000 gross tons of iron ore, 800,000 tons of metallic copper, considerable silver, nickel and some gold, have been extracted and marketed.

Copper Mining.—In no part of the world has the engineer done better work than in the Lake Superior iron and copper regions. The depth to which the workings have been carried, and the expense of fuel, encourage, at some of the mines, the most elaborate and economical machinery. The plant at the workings of the Calumet and Hecla Company is unexcelled in its equipment. This company now has a vertical shaft 4,700 feet; and a neighboring mine, the Tamarack, has two vertical shafts, each 4,450 feet deep. These shafts being located at an elevation of 650 feet above Lake Superior, extend far below the bottom of that

lake, and, in fact, nearly three-quarters of a mile below the ocean level. (See *Fig. 1.*)

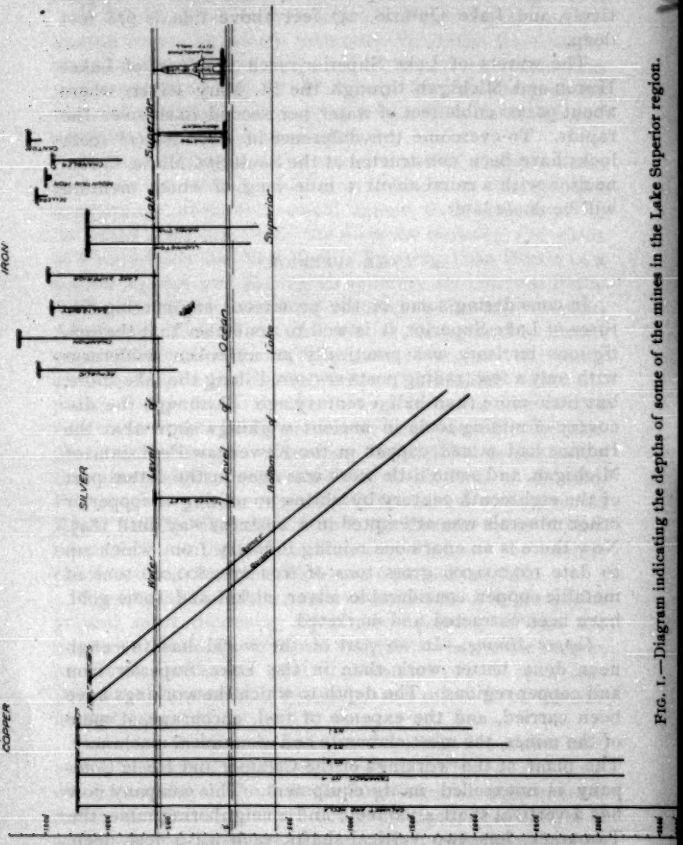


FIG. 1.—Diagram indicating the depths of some of the mines in the Lake Superior region.

It may be instructive to compare the operation of the Lake Superior copper mines with their most active competi-

tor. The mines of the Anaconda Copper Mining Company, in Montana, have produced in fifteen years 400,000 tons of fine copper, with considerable silver and gold, the operations being now 1,200 feet deep. In the same period over 580,000 gross tons of copper were obtained from the Lake Superior mines, but the present output of copper from the Lake Superior region is less than that of Montana.

To illustrate the class of machinery at the Calumet and Hecla copper mines, the dimensions of one pair of quadruple expansion engines, of Philadelphia manufacture, may be given. Each engine has its four cylinders, 18 inches, 27¾ inches, 48 inches and 90 inches in diameter, with a stroke of 60 inches, driving through gearing, conical hoisting drums, 14 feet to 24 feet in diameter, and 12 feet wide, which lift cages carrying 6 tons of ore at the rate of a mile in one and one-half minutes.

At the Tamarack mine an average hoisting speed of 3,200 feet per minute has been obtained by a direct-acting engine built in Milwaukee: having 42 x 84 inch steam cylinders, driving hoisting drums 30 feet in diameter. At the same mine a 32 x 84 inch engine operating a double cone drum 13 feet 6 inches to 36 feet diameter, lifts a cage carrying 2½ to 3 tons 4,500 feet in one and one-half minutes. These are vertical shafts.

At the Quincy mine there are two principal shafts. No. 6, on a slope of 51° 44′, has a total depth of 3,680 feet, the weight of the loads hoisted being about 6 tons. No. 2 shaft, with the same average dip, has a total depth on the slope of 3,954 feet, the loads hoisted weighing about 10 tons each. The governors of the hoisting engines are set so that the maximum speed does not exceed 3,000 feet per minute.

Other important mines in the copper region could add points of interest in the extent of underground workings, machinery equipment, concentrating plant, including pumping machinery of great capacity, refining works, or even in the handling and distribution of the refuse slimes.

As an instance of the economic results achieved in this district the Atlantic mine may be mentioned, which obtains the copper-bearing rock at an average depth of 1,800 feet

below the surface. The rock is mined out with explosives, sent to the surface, crushed, hand-sorted, carried to concentrating mill, passed through stamps, to jigs and slime tables, the concentrate is finally conveyed to a smelting works, and the entire operation was carried on with a profit, although the ore yielded but three-fourths of 1 per cent. of copper, and but 10 cents per pound was obtained for the refined metal. In other words, the operation of this mine was successful and profitable when the company received but $1.70 for each ton of "pay-rock" which was mined, crushed, pulverised, concentrated, and the metal refined.

As indicating what has been accomplished in the copper district, the operations of the Quincy Mining Company may be quoted. On a paid-in capital of $200,000, dividends of $7,670,000 had been paid to the close of 1895, the total expenditures having exceeded $20,000,000. During the year 1895, the average force employed was 968 men, of whom 336 were miners, earning an average of $50 each per month. 563,560 tons of rock were mined, from which 16,304,721 pounds of copper were obtained. Still larger figures could be used to indicate the operation of several other mines.

Silver and Gold.—Near Thunder Cape (1,300 feet above the lake), and three-fourths of a mile from the Canadian shore of Lake Superior, is Silver Islet, originally a mass of rock 90 x 90 feet (approximately equal in area to four ordinary city building lots), which projected a few feet above the lake surface, but which has been docked and cribbed until 3 acres are enclosed, to accommodate the shaft house, shops and miners—barracks for operating the mine, from which $3,000,000 in silver have been obtained. Operations were continued to a depth of 640 feet, and extended horizontally 500 feet under Lake Superior. While the enterprise (owing to the expense of mining the limited amount of ore) cannot be considered as having been successful, its bold engineering features are worthy of recognition.

Most of the silver sent from the Lake Superior region occurs in a native state in connection with copper on the Keweenaw Peninsula. Gold mining has been carried to a depth of 850 feet near Ishpeming, Mich., and newer opera-

tions to the northwest of Lake Superior have been started.

Iron Ore Mining.—The practical exploitation of Lake Superior iron ores, which have developed an enormous trade, occurred about the same time the copper mines were first operated; but beyond treating the ores in local forges, little use was made of them until the year 1856, when the first iron ore was shipped from Marquette. For a long time the range near Marquette, which bears its name, supplied all of the ore, but in 1877 the Menominee range to the south was exploited, and opened for business. While this range is considered, as in the Lake Superior region, most of its ore is shipped via Lake Michigan, thus saving the delay of locking through the St. Mary's Ship Canal, and having less detention from ice in winter. Seven years later the third and fourth ranges, the Gogebic in Michigan and Wisconsin, and the Vermilion in Minnesota, were opened, and within the past three years another range, the Mesabi in Minnesota, has been attracting attention by the size and character of its deposits, and the ease with which the ore is won. As new ranges were discovered and new mines opened, markets were found for the increased outputs, and nearly 10,500,000 tons were sent from the mines of the Lake Superior district in 1895, enormous quantities having been obtained from individual operations. Up to the close of 1895, eleven mines had each contributed totals of from 3,000,000 to 6,800,000 long tons, as much as 1,000,000 tons were produced by a single operation in one year, and for a decade the average output of one mine has been 500,000 tons per year, while several mines for shorter periods had records almost as large. The total amount of iron ore which has been won from the Lake Superior iron ore mines to date exceeds 100,000,000 gross tons.

Some of the hoisting plants at these mines are excellent examples of mechanical construction, but none are as elaborate as that above described at the Calumet and Hecla copper mine. The Chapin iron ore mine has a vertical compound pumping engine, with cylinders 50 and 100 inches in diameter and 10 feet stroke, designed to deliver 3,000 gal-

lons per minute from a depth of 1,500 feet. The plunger pumps, 28 inches in diameter and 10 feet stroke, are connected to the engine through a horizontal beam, and also to a 40-feet fly-wheel weighing 160 tons.

At this same mine the entire power equipment is arranged to work either with steam or with compressed air, the latter being developed by a waterfall 3 miles distant, and conveyed to the mine in a 30-inch wrought iron pipe laid on the surface and fitted with expansion joints. One of the shafts of the Chapin mine was sunk through quicksand by freezing the sand into solid masses, which were then blasted out.

The methods of mining iron ores vary, according to the character of the deposit, from stripping and mining with the steam shovel, to working with rock drills 1,450 feet below the surface of the earth. Some mines are wrought open cut, but the majority are operated underground, all the different methods of long wall mining, caving, milling, overhand and underhand stoping, as well as the various systems of timbering and filling, being in active use in the iron ore mines of Lake Superior. The character of the ore also varies from soft material, easily handled by the shovel, to rock so hard as to severely test the tools and apparatus employed. Rock drills of the same size and working under similar pressures, which bored 100 to 120 feet in ten hours in the limestone of the Chicago drainage canal, could not cut more than 5 to 6 feet in hard Minnesota, and 18 to 20 feet in hard Marquette ores, in the same time.

A statement of the cost of mining ore at one of the large iron ore mines, from a depth of 500 feet below the surface, shows:

	Cents Per Ton.
Actual mining cost, including labor, explosives, light, etc.	44
To which must be added timbering	6
Operating machinery and office expenses	6
Repairs	3¼
Loading and sorting ore	3¼
Insurance and other expenses	2½
A total for ore loaded on cars of	65

for all charges at the mine except royalty and interest

This was an ore of medium hardness, and the quantity of water handled was not excessive.

Iron Ore Shipping Docks.—For the shipment of the iron ore mined in the Lake Superior region, a score of docks fitted with pockets have been erected, at a cost of about $5,000,000. Some of the older docks have been abandoned, and the newer ones embody improvements as to construction, height, handling appliances, etc., and, although the details have been carefully studied out, the cost is sufficiently great to make an appreciable charge for interest and maintenance on each ton of ore handled. The following figures will give an idea of one of the later constructions:

The dock of the Duluth, Mesabi and Northern Railroad, at Duluth, extends into the bay 2,850 feet, its surface being 52·8 feet above the water level, and is equipped with 384 pockets, each with a capacity of 135 tons when trimmed, so that the storage of the dock may be taken in round numbers as 50,000 tons. These pockets are reached by four tracks on the deck of the dock, on which cars with drop bottoms are run. The dock and its approach required 9,250,000 B. M. feet of lumber, and cost $436,000. Twelve boats can be loaded at a time, and 43,000 tons of iron ore have been sent forward from this dock in one day. During the shipping season of 1894 the average cargo delivered per vessel was 2,070 tons, and the average time loading was four hours and seven minutes; but in one instance 2,350 tons of iron ore were placed in a boat in forty-five minutes.

The dock at Marquette, with 270 pockets and very short approach, cost $237,000, and in round numbers a dock proper may be estimated at $1,000 per pocket, or $10 per ton capacity.

The ore shipping docks, although differing in length, width and height, are constructed upon one general plan, viz.: a series of pockets, supported on framing which rests on piles, the pockets each terminating in a door to control the flow of ore into a steel spout weighing 2,500 pounds, which is let down so as to discharge the ore into the hatches of vessels. Over these pockets are the railroad tracks, on which ore is carried by drop-bottom cars.

The length of the twenty iron ore shipping docks, independent of approaches, varies from 559 feet to 2,304 feet, the aggregate of all being about 27,000 feet, or say 5 miles; they contain over 4,200 pockets, and have a capacity of 600,000 long tons, costing approximately $5,350,000. Two more are now building.

Statistics show that the capital invested in the Lake Superior iron ore mines and their equipments amounts to $100,000,000; in iron ore, shipping and receiving docks with approaches, etc., at ports of Lakes Superior and Michigan, $14,000,000; in railroad transportation for iron ore, exclusively to ports on the lakes above-mentioned, $32,000,000; in vessels which are chiefly engaged in the iron ore traffic, $47,000,000; in docks on Lake Erie between Toledo and Buffalo, for receiving and shipping iron ore, $15,000,000; and in railroad transportation of the ore from lower lake ports to furnaces, $28,000,000. The total amount of capital invested in the Lake Superior iron ore trade exclusively is over $250,000,000.

Coal Receiving Docks.—The iron ore shipping docks of Lakes Superior and Michigan are well supplemented by coal receiving docks, where equipments of labor-saving machinery take the coal from the holds of vessels and deliver it onto great stock piles, or directly onto cars.

The shipments of coal from Lake Erie ports to Lake Superior have aggregated 3,000,000 net tons in one year, and in the past five years, 13,000,000 net tons have passed westward through the St. Mary's Ship Canal.

While the coal receiving docks are equipped with various devices, most of them may be described as having a hoisting arrangement to lift the loaded buckets from the vessel's hold sufficiently high to drop their contents into cars which run back on trestles and dump automatically, although in some cases the pockets are carried over the stock pile. One impressive plant has immense dome-shaped storage sheds into which the ore is delivered, and from which it is discharged by mechanical conveyors. Another interesting feature is a battery of coke ovens at West Superior, in which coal brought from the lower lakes is coked, a practice

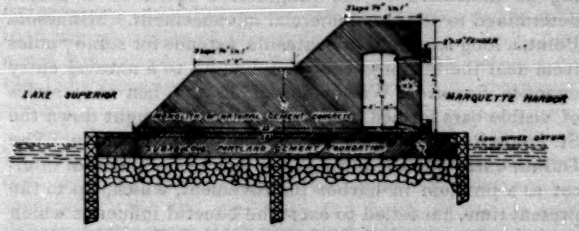
which will probably grow with the development of iron production close to the ore mines, where good ores, but not of the quality to stand long shipments, can be cheaply obtained.

Harbor Improvement.—The work of the engineer is evident at Duluth, Superior, Ashland, Marquette and elsewhere, where railroad lines terminate on the upper lakes in enormous grain elevators, flour and lumber mills of great capacity, and representing advanced construction and equipment, while the harbor improvements on the Great Lakes have demanded large outlays of money and the highest engineering skill.

In this connection, the canal entry at Duluth, is interesting as indicative of the progressive spirit of a people determined to attain commercial advancement. Minnesota Point, a long sand spit or peninsula, extends for some 7 miles from near the business center of Duluth to a natural entry opposite Superior, Wisconsin, and is the last of a series of visible bars formed by detrital matter brought down the St. Louis River, meeting the wave action of the lake. The Duluth entry was cut through the peninsula, and is of interest as a problem in harbor improvement, which, up to the present time, has failed to exert the baneful influence which skilled engineers prophesied. A vessel buffetted by severe storms may in a few moments, by means of this short canal, pass from the tempest-tossed waters of Lake Superior into the calm surface of the commodious harbor, known as Superior Bay.

At Marquette, Mich., there is being constructed a breakwater 3,000 feet in length, composed of béton blocks, under the personal direction of Mr. Clarence Coleman, U. S. Assistant Engineer, from plans prepared by Major Sears, U. S A. The blocks (each one weighing 100 tons) form an entire section of the breakwater, 10 feet in length, and are monoliths, moulded in place on a Portland cement subaqueous foundation. The stone used is a hard quartzite, broken to 2-inch and 1½-inch sizes. The mortar was made of Portland cement for all subaqueous work, and with natural cement for the blocks, mixed with coarse, water-

washed sand, obtained from the shores of Lake Superior. The concrete base, 2 feet thick, rests upon the crib work of the old breakwater, burlap being spread upon the filling stone in the cribs to receive the Portland cement concrete and prevent undue wash from the bottom. Upon the sub-aqueous work is constructed the monolithic béton blocks, which are moulded in alternate sections of 10 feet in their longitudinal direction, the intervening spaces of 10 feet between the blocks being subsequently filled in by special forms, making the whole structure continuous. Horizontal planes of weakness are avoided by completing a block without any intermission in depositing concrete when work has once commenced. Vertical planes are created by mould-



CROSS SECTION OF CONCRETE SUPERSTRUCTURE OF BREAKWATER MARQUETTE MICHIGAN

FIG. 2.

ding in sections of 10 feet, so that any settlement which may happen in the crib work will only affect the block under which it may occur; and by cushions of tarred paper, placed between the blocks, it is expected to avoid the consequences of contraction and expansion in the mass of concrete.

The breakwater has a base of 28 feet in width of Portland concrete, and 23 feet base for the monolithic block, which shows 9 feet 3 inches above the Portland cement base on the harbor side. The gallery, which extends for the entire length of the structure, is intended to be used in giving the keeper access to the harbor light on the outer end of the breakwater during heavy storms. (See *Fig. 2.*)

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FIG. 3.—ROCK CUT, CHICAGO DRAINAGE CANAL. SHOWING A CANTILEVER CONVEYOR, AND THE BLASTING OF ROCK ACROSS THE FACE OF THE CANAL.

It will be understood that the structure is intended to be used solely as a breakwater, and is not in any sense a pier for the convenience of vessels.

LAKE MICHIGAN.

Although but few of the points of engineering interest in the Lake Superior region have been indicated, attention may now be devoted to two specialties on Lake Michigan, which also abounds in notable works. Chicago, a great city built up from low ground, alone presents a long array; her water supply and sewage disposition, her harbor, her numerous bridges, her river tunnels, her network of railroads, her great industries, her iron and steel manufacture, now rivalling that of Pittsburgh, Pa., all represent advanced engineering science. It is authoritatively stated that in the season of navigation more tons of freight go from Chicago eastward by water than by rail, a large proportion of the lake fleet prorating with the railways at Erie, Cleveland, Buffalo, etc. In this arrangement the rate by boat per ton mile is about one-fifth to one-sixth that of the connecting railways. "For the longest lake routes 900 miles from Buffalo to Chicago, 1,000 from Buffalo to Duluth, the rate on grain has approximated 60 cents per ton in recent years. The return on coal has been to Chicago 50 cents, and to Duluth as low as 25 cents, or less than is paid to have it shovelled from the gutter across the sidewalk to the coal hole of the city consumer."

Chicago Drainage Canal.—At present, public attention is directed to the great work of the Chicago Drainage Canal, primarily designed to discharge the sewage of the city of Chicago through the Illinois and Mississippi Rivers and furnish a large amount of water-power, but which its projectors hope will ultimately connect the lakes with the Gulf of Mexico for the purposes of navigation.

This canal, with depths of from 22 to 26 feet, has a greater area of gross section than either the Suez, Manchester or North Sea Canals.

The work is carried on under the laws of the State of Illinois, which provide for a commission to take lands, raise

money and make contracts, the cost of construction being borne by the city of Chicago, under what is known as the Drainage District, and the moneys raised by taxation. The canal is now being built between Chicago and Lockport, a distance of about 34 miles; 12 or 14 miles of this work is through rock; 10 miles through clay, and 10 miles through a mixture of clay, indurated earth and rock, the rock lying in the bottom.

The rock sections are 160 feet wide and about 32 feet deep, In sections where the earth overlies the rock a retaining wall is built from the rock up to the top of the bank. The entire earth sections are sloped; the width in the bottom of the earth sections running from 108 to 160 feet, and the top from 200 to 320 feet; the sides are to be rip-rapped. The top lifts of the dirt sections have been taken off generally with wagons and wheel scrapers, while the bottom lifts have been taken out with steam shovels and tram cars. The average price of the rock excavated per yard has been about 76 cents, dirt sections from 22 to 28 cents per yard. The Desplaines River also had to be diverted and straightened for about 14 miles, and was excavated 200 feet wide and about 4 feet deep.

On the rock sections the top lifts were taken out with inclines and carts, the two lower benches being removed either with cantilevers, cableways or with swing derricks. The most successful work has been credited to the cantilevers and the cableways, but the swing derricks have done good service.

Mr. James F. Lewis, of Chicago, reports that the cableways cost about $12,000, the cantilevers $28,000 each. But one contracting firm owned cantilevers, other firms employed cantilevers, etc., the rock being taken out under contract by the Hoisting Company. The original contractors put the material into the buckets, the sub-contractors supplied the equipment and power for hoisting and dumping it.

The first operation on the canal, after taking off the top soil on the rock sections, was channelling down the sides with channelling machines, the cut being made in three benches. After this from fourteen to sixteen holes were

drilled in a row across the 160 feet section, from 10 to 12 feet back of the face. These holes were fired simultaneously by electricity. It is reported that the blasting was accomplished with an average consumption of one-half pound of 40 per cent. dynamite to the cubic yard. This cost the parties 10 cents per pound, delivered on the work. (See *Fig. 3.*)

This work has demonstrated that about 4 to 5 yards of rock per man could be handled in carts, about 6 to 8 in cars, and from 8 to 10 with cantilevers and cableway buckets per day.

The greater part of the drilling, pumping and some hoisting, has been done with compressed air, one air plant covering one mile of work, but several sections have been operated entirely with steam from a number of boilers; however, the general verdict is strongly in favor of compressed air. Mr. Lewis states the rock drills have bored all the way from 90 to 130 feet per day, or 13 feet per hour.

The fall of 1896 should see the canal to the city line completed for the 34 miles, but it will not achieve its purpose until Chicago builds lateral canals to cut off the sewage which now runs into the lake. These lateral canals will turn all the sewage into the Chicago River and from that into the canal.

The amount of rock excavation exceeds 12,000,000 cubic yards, and the total quantity of rock and earth to be moved is about 40,000,000 cubic yards; when completed the work will have cost $27,000,000.

Thus Chicago is expending $27,000,000 for its drainage, with a possibility of improved transportation facilities, while the State of Pennsylvania hesitated to appropriate 2 per cent. of that amount to facilitate the removal of obstructions in the Delaware River, which are driving trade away from this stream.

The following data concerning the labor employed and wages paid is excerpted from a report by Joseph Gruenhut, labor statistician:

"For summer months the following working force was employed (more or less) on the canal by the contractors on all sections: 45 superintendents, 32 bookkeepers and clerks,

280 foremen and time-keepers, 3 civil engineers, 73 steam shovel engineers, 73 crane men, 12 first levermen, 8 second levermen, 12 first hookers, 12 second hookers, 9 riggers, 7 cableway repairers, 240 engineers and pumpmen, 275 firemen, 50 trainmen, 210 drillers, 113 channellers, 11 electricians, 37 machinists, 100 stone masons, 101 carpenters and 17 helpers, 69 blacksmiths and 46 helpers, 12 boiler-makers and 7 helpers, 1 oil man, 1 tool man, 50 watermen and boys, 450 teamsters, 6,000 laborers—a total of 8,356.

"The number of persons employed in the commissary and in the camp boarding houses may be estimated at 344, which would make a grand total of 8,700 persons directly paid in the camps of the Drainage Canal.

"The average wages on the Drainage Canal are as follows:

"*Daily Wages*—Laborers, $1.50–$1.75; teamsters, $1.50–$1.60; drillers, $1.75–$2.00; trainmen, $1.75–$2.00; firemen, $1.75; channellers, $2.50–$3; first levermen, $2.20; second levermen, $1.50; first hookers, $1.75; second hookers, $1.50; riggers, $2.25; cableway repairers, $2.25; machinists, $2–$2.50; carpenters, $2–$2.25; blacksmiths, $2.50–$3; boiler-makers, $3.50; stonemasons, $3.50–$4.

"*Monthly Wages*—Superintendents, $100–$150; time-keepers, $50–$100; bookkeepers and clerks, $60–$125; foremen, $60,–$80; engineers and pumpmen, $50–$80; electricians, $75–$90; civil engineers, $90–$100; steam shovel engineers, $125; cranemen, $90–$100."

Screw Pumping Engine.—The city of Milwaukee has an interesting installation in a screw pumping engine, which, by discharging a large volume of water from Lake Michigan into the Milwaukee River, flushes away sewage which had become a nuisance. A four-bladed propeller, 14 feet in diameter, keyed to the crank shaft of a vertical compound engine, with steam cylinders 19 and 38 inches in diameter and 4 feet stroke, causes, at fifty-two revolutions per minute, a volume of 40,000 cubic feet per minute to pass through a tunnel ½ mile long into the river, which, at the discharge, is 3 feet above the ordinary lake level. When tested, a duty of 76,000,000 foot-pounds per 100 pounds of coal fired, or

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FIG. 4.—"WHALE-BACK" PROPELLER AND BARGE IN THE AMERICAN LOCK, SAULT STE. MARIE, MICH.

102,000,000 foot-pounds per 100 pounds of steam used, was reported.

Milwaukee, like Chicago, has powerful and economical engines for water supply and for sewage disposal, a tunnel into the lake for water, breakwaters, swing bridges, imposing buildings, large industrial and railroad structures, etc.

ST. MARY'S SHIP CANAL.

A statement of the commerce through the St. Mary's Falls Canal since its opening in 1855 would be practically a *résumé* of the progress of what may be called the Lake Superior district, and an indication of the rapid development of the northern portion of the United States, and yet this would not include the great traffic which did not reach Lake Superior, for vessels from Lake Michigan and the lower lakes do not have to pass this canal.

To illustrate how progress has exceeded expectations, it is interesting to refer to a letter written by the late E. B. Ward, of Detroit (one of the most progressive men of his time), who in 1853 expressed a conviction that a lock 350 feet long and 70 feet wide would be larger than would ever be needed for the Lake Superior traffic, and stated that he considered a lock 260 feet long by 60 feet wide ample for the present century.

The two locks constructed in 1855, however, were made 350 feet by 70 feet, with a lift of 9 feet each, and passed vessels drawing 12 feet of water. In the first ten years of their existence the registered tonnage annually passing increased from 100,000 to 570,000, being augmented in the second decade to over 1,000,000 tons. The demands of lake traffic soon required a new lock, which was completed in 1881, its length being 515 feet, width 80 feet (narrowed at the portals to 60 feet), the lift was 18 feet, with a depth of 16 feet on the mitre sill. For years this lock has been totally inadequate, and during the season of navigation there has been a continued congestion of vessels both above and below, it having passed, during seven and one-half months in the year 1895, 16,793 vessels, with a total registered tonnage of over 16 000,000. (See *Fig. 4.*)

The report of the Manchester Ship Canal shows that in 1895 the tonnage passing through it was but one-tenth of that passing the St. Mary's Ship Canal. Since 1891 the traffic through the Suez Canal, in twelve months, has been below that of the St. Mary's Canal for less than eight months, the number of vessels for three years being:

	1893.	*1894.*	*1895.*
Suez Canal, 12 months	3,341	3,352	3,434
St. Mary's Ship Canal, 8 months .	12,008	14,491	17,956

A new lock, 800 feet long and 100 feet wide throughout, with a lift of 18 feet and a depth of 21½ feet on the mitre sill, is nearly completed, at a cost of $5,000,000, and will be opened by the United States Government to commerce in 1896, while on the opposite side of the St. Mary's River the Canadian Government have within the last few months opened for traffic a lock 900 feet long and 60 feet wide.

To those familiar with the locks used on our ordinary river canals, a recital of dimensions scarcely makes them appreciated. To assist such appreciation we may consider that to fill this new 800 x 100 feet lock will require 11,000,000 gallons of water, that each of the wings of the lower gate, which are made of steel, weigh 175 tons, and that four fairly large vessels, say 350 to 375 feet long, can be carried through at a single lockage.

The value of the over 13,000,000 tons of freight passing the present lock during the seven and one-half months that navigation was open in the year 1894, exceeded $143,000,000, and as the average distance the freight was carried by water was 821 miles, the traffic represented a total ton-mileage of 11,000,000,000, the cost of carrying per ton-mile being slightly less than one mill. Corresponding figures for the traffic of 1895 are now in the course of preparation.

The freight which passed through the St. Mary's Canal in 1894 as represented by the values may be generally subdivided thus: 40 per cent. flour and wheat, 14 per cent. copper, 12 per cent. iron ore, 8 per cent. lumber and 6 per cent. coal, the balance being unclassified and diversified freight.

An idea of the quantities moved, however, may be had

from the 2,750,000 tons of coal, 6,500,000 tons* of iron ore, 9,000,000 barrels of flour, 36,000,000 bushels† of grain, 250,000 barrels of salt, 60,000 tons of iron, 100,000 tons of copper, 723,000,000 feet B. M. lumber, etc.

[*To be concluded.*]

CHEMICAL SECTION.

Stated Meeting, held April 21, 1896.

DR. HARRY F. KELLER, President, in the Chair.

SEPARATION OF SILVER FROM GOLD BY VOLATILISATION.

BY DR. JOSEPH W. RICHARDS, of the Lehigh University.

In making the quantitative blowpipe assay for gold and silver, it is usual to treat 100 milligrams of ore at a single fusion, yielding buttons which are too small to be weighed accurately, but whose weight must be found by measuring carefully their horizontal diameters.

As determined by Plattner (and often verified in the writer's experience), silver buttons weigh 0·6346 of the weight of spheres of silver of the same diameter as measured, and gold buttons 0·7506 of the weight of gold spheres. The buttons obtained usually weigh 0·5 to 1·5 milligrams, and the separation of the silver from the gold in buttons so small is a matter of considerable difficulty. Plattner remarks that no satisfactory method of separation in the dry way is known, and recommends the parting by nitric acid. Working, however, with buttons smaller than pin-heads, it is extremely difficult to boil two or three times with nitric acid, to wash until the silver salt is all removed, and then to gather and melt down the gold, without losing a considerable proportion of the gold in three or four directions.

* 8,000,000 tons in 1895.

† 46,000,000 bushels in 1895.

Knowing that, on long heating, silver gives a coating of oxide on charcoal, and that gold does not, I made experiments to determine whether silver could be thus separated from gold, and have found the method practicable. On heating to a bright-yellow heat (not to whiteness) upon charcoal an alloy of gold and silver, before a sharp-pointed oxidising flame, the silver volatilises easily and steadily until there is less than 5 per cent. of silver remaining in the gold. I estimate this volatilisation to take place a little above the melting point of copper, say at 1,100–1,200° C. To remove the remainder of the silver, the heat is raised nearly to whiteness, or to about the melting point of steel (1,500° C). When the silver is entirely eliminated, the gold, at this temperature, begins to volatilise also; in fact, a trace of gold will be carried off with the last of the silver, and if the ash of the charcoal be white it will show a faint crimson coating close to the assay. When this coating is heavy enough to be seen without the use of a lens, the silver has been completely volatilised and the remaining button is pure gold. The amount of gold necessary to give this coating is too small to be determined by weighing or measuring.

Having explained the principle made use of, I will give the further details of conducting the operation. The charcoal should be dense, so as not to burn away too quickly. Too light a charcoal will not stand the five or ten minutes' application of the oxidising flame without burning through the piece. It should also leave a white ash under the oxidising flame, so as to furnish a background on which to see the crimson gold coating which determines the end of the operation. I have found the dense, hard charcoal made by Johnson & Co., of New York, to answer these requirements admirably. It is well, also, to work with a porcelain saucer, or large sheet of clean paper, under the flame, to catch the button in case it should be blown from the charcoal.

In order to perform this separation without excessive exertion, I would recommend that a gas flame not over 2 centimeters high be used, that the tip of the blowpipe be advanced at least halfway through the flame, and inclined

somewhat sharply downwards, at an angle of about 45°. By observing these simple directions, a very sharp-pointed, needle-like oxidising flame will be produced, about 1 centimeter in length to the blue tip, which I have found the best for the purpose in view. To produce this the blowing need not be strong, but it should be kept up steadily. The button, in a shallow cavity near the end of the stick of charcoal, is now brought directly in front of the point of the flame, at about 1 to 2 millimeters from the visible blue tip. Its position, of course, is regulated by the temperature observed. The button ton should not, at this stage, be heated to whiteness, else the silver will boil and cause a loss by sputtering. The charcoal is held inclined towards the flame at an angle of about 30°, so that the flame descends almost vertically upon the button, and thus decreases the liability of its displacement by the force of the blast.

It will be found practicable to continue a blowing for about three minutes without discomfort, at the end of which time the operator may stop to observe the color of the button. Supposing the alloy, on starting, to have been white, it will usually become pale yellow in from three to six minutes. When the alloy exhibits a brass-yellow color, the heat should be raised, and the next blowing continued for not over two minutes. At the end of this time the alloy will usually exhibit nearly the pure gold color, but no gold coating, or, at most, only a trace of it will be seen on the charcoal. After this, the heat should be raised to nearly whiteness, and then continued for not over one minute at a time. If a faint gold coating appears, further heating for one minute will usually develop a distinct crimson coating, visible without the lens, and the alloy will show the pure gold color. It is then taken out, cupelled and measured.

If the amount of gold present be very small, it is difficult to continue volatilising silver after the button gets smaller than ¼ millimeter in diameter. The difficulty is caused by the ash of the charcoal, which, fusing to a slag, envelopes the button. To continue the removal of the silver, should the button arrive at this size without showing the gold color,

the operator cupels and measures a pure gold button of about the same size and adds it to the button being treated. The enlarged button is now worked down to pure gold, as before, removed, cupelled and measured. The weight of gold obtained is diminished by the amount added, the difference giving that in the ore.

If the heating to incipient whiteness be continued two or three minutes after the visible gold coating is obtained, a very pretty gold coating of bright, peach-blossom color is obtained, and a sensible amount of gold is lost by volatilisation. A pure gold button, 1 millimeter in diameter, weighing 7·58 milligrams, lost 0·03 milligrams (0·4 per cent.) each minute that it was heated to whiteness, and in five minutes gave a beautiful crimson coating. A silver button of similar size lost 18 per cent. of its weight, each minute, at only a bright-yellow heat. I estimate the point at which gold begins to volatilise as about the melting-point of soft steel (1,500° C.). It is certainly considerably below the melting-point of platinum (1,775° C.).

In conclusion, I wish to say that I have tested this method of separation in many different ways, with large and small buttons, and upon alloys rich and poor in gold, and have found the separation to be absolute when the conditions above described are properly observed. I have repeatedly alloyed a gold button with different amounts of silver, and then driven off the silver, the button, after two or three of such separations, remaining of exactly the same size and weight as at the start. In proposing this method of separation, I do not wish to disguise the fact that, to ensure success, it demands a steady hand and an experienced operator, and some practice; but I believe that any one who has mastered the art of blowpiping sufficiently to make gold and silver assays, can, in a short time, master this method of separating the gold and silver.

[In the discussion of the above paper, it was suggested that the method might be practicable in the ordinary assay of gold and silver, as, at assay offices, if an electrically heated furnace could be devised, in which the buttons could be placed on suitable supports, and kept at the proper temper-

ature to volatilise silver, with a current of air passing over them. The movement to the hottest part of the furnace would suffice to remove the last traces of silver, just as the last traces of lead are removed in cupellation in an ordinary muffle. The process of removing the silver would then resemble cupellation in its general outlines, except that the temperature would be about 300° to 500° higher.]

ELECTRICAL SECTION.

Stated Meeting, December 19, 1895.

MR. CARL HERING, President, in the Chair.

MECHANICAL CONCEPTIONS OF ELECTRICAL PHENOMENA.

BY PROF. A. E. DOLBEAR,
Tuft's College, Massachusetts.

And now we might add something concerning a most subtile spirit which pervades and lies hid in all gross bodies, by the force and action of which spirit the particles of bodies attract each other at near distances, and cohere if contiguous, and electric bodies operate at greater distances as well repelling as attracting neighboring corpuscles, and light is emitted, reflected, inflected and heats bodies, and all sensation is excited and members of animal bodies move at the command of the will.—*Newton, in Principia.*

In Newton's day the whole field of nature was practically lying fallow. No fundamental principles were known until the law of gravitation was discovered. This law was behind all the work of Copernicus, Kepler and Galileo, and what they had done needed interpretation. It was quite natural that the most obvious and mechanical phenomena should first be reduced, and so the *Principia* was concerned with mechanical principles applied to astronomical problems. To us, who have grown up familiar with the principles and conceptions underlying them, all varieties of mechanical phenomena seem so obvious, that it is difficult for us to understand how any one could be obtuse to them; but the records of Newton's time, and immediately after this, show that they were not so easy of apprehension. It

may be remembered that they were not adopted in France till long after Newton's day. In spite of what is thought to be reasonable, it really requires something more than complete demonstration to convince most of us of the truth of an idea, should the truth happen to be of a kind not familiar, or should it chance to be opposed to our more or less well-defined notions of what it is or ought to be. If those who labor for and attain what they think to be the truth of any matter, were a little better informed about mental processes and the conditions under which ideas grow and displace others, they would be more patient with mankind, and teachers of every rank might discover that what is often called stupidity may be no more than mental inertia, which can no more be made active by willing than can the movement of a cannon ball by a like effort. We grow into our beliefs and opinions upon all matters, and scientific ideas are no exceptions.

Whewell, in his "History of the Inductive Sciences," says that the Greeks made no headway in physical science because they lacked appropriate ideas. The evidence is overwhelming that they were as observing, as acute, as reasonable as any who live to-day. With this view, it would appear that the great discoverers must have been men who started out with appropriate ideas: were looking for what they found. If, then, one reflects upon the exceeding great difficulty there is in discovering one new truth and the immense amount of work needed to disentangle it, it would appear as if even the most successful have but indistinct ideas of what is really appropriate, and that their mechanical conceptions become clarified by doing their work. This is not always the fact. In the statement of Newton, quoted, he speaks of a spirit which lies hid in all gross bodies, etc., by means of which all kinds of phenomena are to be explained; but he deliberately abandons that idea when he comes to the study of light, for he assumes the existence and activity of light corpuscles, for which he has no experimental evidence; and the probability is that he did this because the latter conception was one which he could handle mathematically, while he saw no way for thus

dealing with the other. His mechanical instincts were more to be trusted than his carefully calculated results; for, as all know, what he called "spirits," is what to-day we call the ether, and the corpuscular theory of light has now no more than a historic interest. The corpuscular theory was a mechanical conception, but each such corpuscle was ideally endowed with qualities which were out of all relations with the ordinary matter with which it was allied.

Until the middle of the present century the reigning physical philosophy held to the existence of what were called imponderables. The phenomena of heat were explained as due to an imponderable substance called "caloric," which ordinary matter could absorb and emit. A hot body was one which had absorbed an imponderable substance. It was, therefore, no heavier than before, but it possessed ability to do work proportional to the amount absorbed. Carnot's ideal engine was described by him in terms that imply the materiality of heat. Light was another imponderable substance maintained by Sir David Brewster as long as he lived. Electricity and magnetism were imponderable fluids, which, when allied with ordinary matter, endowed the latter with their peculiar qualities. The conceptions in each case were properly mechanical ones *part* (but not all) *of the time;* for when the immaterial substances were dissociated from matter, where they had manifested themselves, no one concerned himself to inquire as to their whereabouts. They were simply off duty, but could be summoned, like the genii in the story of Aladdin's Lamp. Now, a mechanical conception of any phenomenon, or a mechanical explanation of any kind of action, must be mechanical all the time, the antecedents as well as the consequents. Nothing else will do except a miracle.

During the fifty years, from about 1820 to 1870, a somewhat different kind of explanation of physical events grew up. The interest that was aroused by the discoveries in all the fields of physical science—in heat, electricity, magnetism and chemistry—by Faraday, Joule, Helmholtz and others, compelled a change of conceptions; for it was noticed that each special kind of phenomenon was preceded by some

other definite and known kind; as, for instance, that chemical action preceded electrical currents, that mechanical or electrical activity resulted from changing magnetism, and so on. As each kind of action was believed to be due to a special force, there were invented such terms as mechanical force, electrical force, magnetic, chemical and vital forces, and these were discovered to be convertible into one another, and the "doctrine of the correlation of the physical forces" became a common expression in philosophies of all sorts. By "convertible into one another" was meant that, whenever any given force appeared, it was at the expense of some other force; thus, in a battery, chemical force was changed into electrical force; in a magnet, electrical force was changed into magnetic force, and so on. The idea here was the *transformation of forces*, and *forces* were not so clearly defined that one could have a mechanical idea of just what had happened. That part of the philosophy was no clearer than that of the imponderables which had largely dropped out of mind. The terminology represented an advance in knowledge, but was lacking in lucidity, for no one knew what a force of any kind was.

The first to discover this and to repudiate it were the physiologists, who early announced their disbelief in a vital force, and their belief that all physiological activities were of purely physical and chemical origin, and that there was no need to assume any such thing as a vital force. Then came the discovery that chemical force, or affinity, had only an adventitious existence, and that, at absolute zero, there was no such activity. The discovery of, or rather the appreciation of, what is implied by the term *absolute zero*, and especially of the nature of heat itself, as expressed in the statement that heat is a mode of motion, dismissed another of the so-called forces as being a metaphysical agency having no real existence, though standing for phenomena needing further attention and explanation—and by explanation is meant *the presentation of the mechanical antecedents for a phenomenon, in so complete a way that no supplementary or unknown factors are necessary*. The train moves because the engine pulls it; the engine pulls because the steam pushes it.

There is no more necessity for assuming a steam force between the steam and the engine, than for assuming an engine force between the engine and the train. All the processes are mechanical, and have to do only with ordinary matter and its conditions, from the coal pile to the moving freight, though there are many transformations of the forms of motion and of energy between the two extremes.

During the past thirty years, there has come into common use another term, unknown in any technical sense before that time, namely, *energy*. What was once called the conservation of force is now called the conservation of energy, and we now often hear of forms of energy. Thus, heat is said to be a form of energy, and the forms of energy are convertible into one another, as the so-called forces were formerly supposed to be transformable into one another. We are asked to consider gravitative energy, heat energy, mechanical energy, chemical energy, electrical energy. When we inquire what is meant by energy, we are informed that it means ability to do work, and that work is measurable as a pressure into a distance, and is specified as foot-pounds. A mass of matter moves because energy has been spent upon it and has acquired energy equal to the work done on it, and this is believed to hold true, no matter what the kind of energy was that moved it. If a body moves, it moves because another body has exerted pressure upon it, and its energy is called *kinetic energy*; but a body may be subject to pressure and not move appreciably, and then the body is said to possess potential energy. Thus, a bent spring and a raised weight are said to possess potential energy. In either case, *an energised body receives its energy by pressure, and has ability to produce pressure on another body*. Whether or not it does work on another body depends on the rigidity of the body it acts upon. In any case, it is simply a mechanical action—body *A* pushes upon body *B* (*Fig. 1*). There is no need to assume anything more mysterious than mechanical action. Whether body *B* moves in this way or that depends upon the direction of the push, the point of its application. Whether the body be a mass as large as the earth or as small as a molecule, makes no

difference in that particular. Suppose, then, that *a* (*Fig. 2.*) spends its energy on *b*, *b* on *c*, *c* on *d*, and so on. The energy of *a* gives translatory motion to *b*, *b* sets *c* vibrating, and *c* makes *d* spin on some axis. Each of these has had energy spent on it, and each has some form of energy different from the other, but no new factor has been introduced between *a* and *d*, and the only factor that has gone from *a* to *d* has been motion—motion that has had its direction and quality changed, but not its nature. If we agree that energy is neither created nor annihilated by any physical process, and if we assume that *a* gave to *b* all its energy, that is, all its motion; that *b* likewise gave its all to *c*, and so on; then the succession of phenomena from *a* to *d* has been simply the transference of a definite amount of motion, and, therefore, of energy, from the one to the other; for *motion has been the only variable factor*. If, furthermore, we should agree

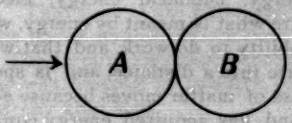

FIG. 1.

to call the translatory motion α, the vibratory motion β, the rotary γ, then we should have had a conversion of α into β, of β into γ. If we should consider the amount of the transference instead of the kind of motion, we should have to say that the α energy had been transformed into β and the β into γ.

What a given amount of energy will do depends only upon its *form;* that is, the kind of motion that embodies it.

The energy spent upon a stone thrown into the air, giving it translatory motion, would, if spent upon a tuning fork, make it sound, but not move from its place; while if spent upon a top, would enable the latter to stand upon its point as easily as a person stands on his two feet, and to do other surprising things, which otherwise it could not do. One can, without difficulty, form a mechanical conception of the whole series without assuming imponderables, or fluids or

forces. Mechanical motion only, by pressure, has been transferred in certain directions at certain rates. Suppose now that some one should suddenly come upon a spinning top (*Fig. 3*) while it was standing upon its point, and, as its motion might not be visible, should cautiously touch it. It would bound away with surprising promptness, and, if he were not instructed in the mechanical principles involved, he might fairly well draw the conclusion that it was actuated by other than simple mechanical principles, and, for that reason, it would be difficult to persuade him that there was nothing essentially different in the body that appeared and acted thus, than in a stone thrown into the air; nevertheless, that statement would be the simple truth.

All of our experience, without a single exception, enforces the proposition that no body moves in any direction, or in any way, except when some other body *in contact* with

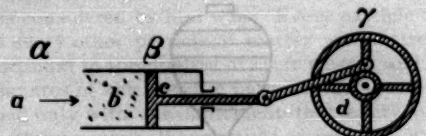

FIG. 2.

it presses upon it. The action is direct. In Newton's letter to his friend Bentley, he says: "That one body should act upon another through empty space, without the meditation of anything else by and through which their action and pressure may be conveyed from one to another is to me so great an absurdity that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it."

For mathematical purposes, it has sometimes been convenient to treat a problem as if one body could act upon another without any physical medium between them; but such conception has no degree of rationality, and I know of no one who believes in that as a fact. If this be granted, then our philosophy agrees with our experience, and every body moves because it is pushed, and the mechanical antecedent of every kind of phenomenon is to be looked for in some

adjacent body possessing energy—that is, the ability to push or produce pressure.

It must not be forgotten that energy is not a simple factor, but is always a product of two factors: a mass with a velocity, a mass with a temperature, a quantity of electricity into a pressure, and so on. One may sometimes meet the statement that matter and energy are the two realities; both are spoken of as entities. It is much more philosophical to speak of matter and motion, for in the absence of motion there is no energy, and the energy varies with the amount of motion; and furthermore, to understand any manifestation of energy one must inquire what kind of motion is involved. This we do when we speak of mechanical energy as the energy involved in a body having a translatory motion; also, when we speak of heat as a vibratory, and of light as a wave motion. To speak of energy, without stating or implying these distinctions, is to speak loosely and to keep far within the bounds of actual knowledge. To speak thus of a body possessing energy, or expending energy, is to imply that the body possesses some kind of motion and produces pressure upon another body because it has motion. Tait and others have pointed out the fact that what is call potential energy must, in its nature, be kinetic. He says: "Now it is impossible to conceive of a truly dormant form of energy, whose magnitude should depend, in any way, upon the unit of time; and we are forced to conclude that potential energy, like kinetic energy, depends (even if unexplained or unimagined) upon motion." All this means that it is now too late to stop with energy

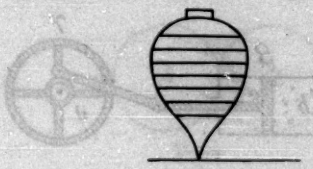

FIG. 3.

as a final factor in any phenomenon, that the *form of motion* which embodies the energy is the factor that determines *what* happens, as distinguished from how *much* happens. Here, then, are to be found the distinctions which have heretofore been called forces; here is embodied the proof that direct pressure of one body upon another is what causes the latter to move, and that the direction of movement depends on the point of application, with reference to the center of mass.

It is needful now to look at the other term in the product we call energy, namely, the substance moving, sometimes called matter or mass. It has been mentioned that the idea of a medium filling space was present with Newton, but his gravitation problem did not require that he should consider other factors than masses and distances. The law of gravitation as considered by him was: Every particle of matter attracts every other particle of matter with a stress which is proportional to the product of their masses, and inversely to the squares of the distance between them. Here we are concerned only with the statement that every particle of matter attracts every other particle of matter. Everything then that possesses gravitative attraction is matter in the sense in which that term is used in this law. If there be any other substance in the universe that is not thus subject to gravitation, then it is improper to call it matter, otherwise the law should read: "Some particles of matter attract," etc.; which will never do.

We are now assured that there is something else in the universe which has no gravitative property at all, namely, the ether. It was first imagined in order to account for the phenomena of light, which was observed to take about eight minutes to come from the sun to the earth. Then Young applied the wave theory to the explanation of polarisation and other phenomena; and, in 1851, Foucault proved experimentally that the velocity of light was less in water than in air, as it should be if the wave theory be true, and this has been considered a crucial experiment which took away the last hope for the corpuscular theory and demon-

strated the existence of the ether as a space-filling medium capable of transmitting light waves known to have a velocity of 186,300 miles per second. It was called the luminiferous ether, to distinguish it from other ethers which had also been imagined, such as electric ether for electric phenomena, magnetic ether for magnetic phenomena, and so on—as many ethers as there were different kinds of phenomena to be explained.

It was Faraday who put a stop to the invention of ethers, by suggesting that the so-called luminiferous ether might be the one concerned in all the different phenomena, and who pointed out that the arrangement of iron filings about a magnet was indicative of the direction of the stresses in the ether. This suggestion did not meet the approval of the mathematical physicists of his day, for it necessitated the abandonment of the conceptions they had worked with, as well as the terminology which had been employed, and made it needful to reconstruct all their work to make it intelligible—a labor which was the more distasteful as it was forced upon them by one who, although expert enough in experimentation, was not a mathematician, and who boasted that the most complicated mathematical work he ever did was to turn the crank of a calculating machine; who did all his work, formed his conclusions, and then said: "The work is done; hand it over to the computers."

It has turned out that Faraday's mechanical conceptions were right. Everyone now knows of Maxwell's work, which was to start with Faraday's conceptions as to magnetic phenomena and follow them out to their logical conclusions, applying them to molecules and their reactions upon the ether. Thus he was led to conclude that light was an electro-magnetic phenomenon; that is, that the waves which constitute light and waves produced by changing magnetism were identical in their nature, were in the same medium, traveled with same velocity, were capable of refraction, and so on. Now, that all this is a matter of common knowledge to-day, it is curious to look back no further than ten years. Maxwell's conclusions were adopted by scarcely a physicist in the world. Although it was known that inductive action

traveled with finite velocity in space, and that an electro-magnet would affect the space about it practically inversely as the square of the distance, and that such phenomena as are involved in telephonic induction between circuits could have no other meaning than the one assigned by Maxwell, yet nearly all the physicists failed to form the only conception of it that was possible, and waited for Hertz to devise apparatus for producing interference before they grasped it. It was even then so new, to some, that it was proclaimed to be a demonstration of the existence of the ether itself, as well as a method of producing waves short enough to enable one to notice interference phenomena. It is obvious that Hertz himself must have had the mechanics of wave motion plainly in mind, or he would not have planned such experiments. The outcome of it all is, that we now have experimental proof, as well as theoretical reason, for believing that the ether, once called luminiferous, is concerned in all electric and magnetic phenomena, and that waves set up in it by electro magnetic actions are capable of being reflected, refracted, polarised, and twisted, the same as ordinary light waves can be, and that the same laws are applicable to both.

But this ether has been studied in other ways. The light of stars reaches us from space depths so profound that it requires thousands of years, traveling at the high rate of 186,000 miles a second, to reach the earth, and every increase of aperture of our telescopes shows the existence of others still more remote.

For us, the ether is practically *illimitable*; it has no boundaries. If it had boundaries, light waves would be reflected from it in every direction, and the whole canopy of the sky would be luminous all the time. Investigation as to the minuteness of some waves and the conditions for producing such waves has led to the conclusion that the ether is not granular; that is, it is *non-atomic*. It is described as being a *continuous* medium, to signify that there are no pores or interstices in it, another quality that distinguishes it sharply from gravitative matter. Neither is there any evidence that it is subject to friction, for bodies which have been moving

in it for no one knows how long have not had their rates of motion changed by it. Comets have been known to move in the neighborhood of the sun with the velocity of nearly 400 miles per second, and not to suffer retardation, and light itself does not appear to be absorbed, in any degree, by traveling in it for any length of time. If it were, some stars would be coming into view in the direction in which the solar system is traveling, and others in the opposite direction would be dropping out of sight. Hence, we speak of it as being a *frictionless* medium.

Its qualities are alike in every direction; that is, it is *isotropic*.

It is all alike; there are no species of it; it is *homogeneous*.

It is capable of transmitting energy of certain forms with the velocity of light, and ability to do this is attributed to *elasticity*, though it is obvious that such elasticity as it has is wholly unlike the elasticity of any body of matter.

It is believed to be incapable of deformation; that is, its rigidity is incomparably greater than that of steel.

It is *incompressible*. Its *density* has been computed on the assumption that its ability to transmit energy is dependent upon the same physical conditions that enable matter to transmit it; but it is evident that the term is not to be understood to mean what we mean when we speak of the density of the earth or of the sun; for a body which is not capable of compression and is without molecular structure, can hardly be compared with one which is.

To describe the ether, there is evidently a necessity for appropriate terms, which, at present, we do not possess.

There is a certainty that it is capable of stress or pressure, for the phenomena of electricity and magnetism show this conclusively; and most astronomers, from Newton to those now living, have deemed it highly probable that the phenomena of gravitation are due to the action of this medium, rather than that one body can act upon another without it—that is, the ether pushes them towards each other—and attraction in the old sense has little to support it. Moreover, the velocity of gravitative action is believed

to be not less than a million times that of light, and this shows that the character of the action that produces the gravitative pressure is totally different from that which sets up ordinary waves in the ether.

It appears, also, that the ether is a reservoir of energy of various kinds—energy which has been computed to be not less than 500 horse-power per cubic inch. It is capable of transforming energy—the energy of matter—and it holds what it gets until it can act upon some other mass of common matter; but it is capable of exchanging energy with matter. Thus, when a body like a weight is raised, work is done upon the ether, and exists as a stress in it. When the weight falls, the ether gives it back. When a hot body loses its heat by the process called radiation, the ether receives the energy as wave motion, and at once begins to distribute it. The energy is transformed from vibratory, in the molecules, to undulatory, in the ether, and, on meeting other molecules, is again transformed into heat. In like manner, with electric and magnetic actions, there is an exchange of energy from matter to ether, or *vice versa*.

Here are many ether phenomena, so utterly unlike the phenomena of ordinary matter that it is apparent the name matter ought not to be applied to it. Furthermore, it is also apparent that all attempts to describe the properties of the ether in the terms applicable to matter will be misleading. Here is a substance, which, experimentally, shows itself to be illimitable, continuous, homogeneous, isotropic, non-atomic, frictionless, incompressible, incapable of transforming its own energy, gravitationless, insensible to all nerves, compared with what is limited, discontinuous, heterogeneous, eolotropic, atomic, frictionable, compressible, capable of transforming energy, gravitative, and upon which all nerve action depends. Are not these distinctions wide enough to make one beware of thinking of them and describing their phenomena in the same terms?

[*To be concluded.*]

Stated Meeting, Tuesday, March 24, 1896.

MR. CLAYTON W. PIKE, President, in the chair.

INHERENT DEFECTS IN FUSE METALS EXPERIMENTALLY CONSIDERED.

BY WALTER E. HARRINGTON.

The development of the electrical arts, in the last few years, particularly in the direction of lighting and motive-power transmission, has been very great.

The fire risk, as well as the risk from failure of insulation and apparatus involved in electric work, is present in a greater or less degree, in accordance with the provision of the proper safeguards and selection of the best conditions. Notwithstanding the adoption of all provisions for protection and proper maintenance, safety devices are necessary, inasmuch as it is their purpose to provide for abnormal conditions, and to remove risks, which, although usually absent with perfect working and maintenance, may be brought into existence by accident or unforeseen defects. Such risks may be occasioned by outside interference with lines; or by lighting; by falling of poorly constructed signal and other wires upon overhead wires; by unusual wind or sleet storms; by failures of all kinds, as in the working of lamps, switches, etc. It is here that the safety device is found to be useful. Such devices are to the electrical system what check valves, overflow traps and safety valves are to steam and hydraulic systems. There is, of course, no room for doubt that if the insulation of all parts of the plant, as dynamos, lines, lamps, etc., were maintained always at its best, and if the mechanical strength of lines, hangers, poles, etc., could always be relied upon, and, further, if the effects of lightning induction were never present; there would be but little use for any purely electrical safety appliances, such as those for guarding against leaks and diversions of current. To expect such perfection of conditions

is to expect too much. There will always remain opportunity for unskilled or careless handling so altering the conditions as to provoke troubles. There will always remain chances of undiscovered defects, chances of interference from outside. It is evident, therefore, that safety devices are and will continue to be important factors in electric work.

The last few months has witnessed a most remarkable awakening of interest in the question of the protection of electric circuits—an interest that is the more marked because of the entire lack of attention and misunderstanding formerly displayed. Engineers, boards of fire underwriters and municipal authorities, are realising that pronounced and heroic steps must be taken to prevent the recurrence of troubles occasioned by the present unreliable methods of protecting electric circuits. Mr. Wm. McDevitt, Chief Inspector of the Philadelphia Board of Fire Underwriters, one of the most conservative men in the profession, and possessed of ripe and broad experience in these matters, has recently put himself upon record in a paper, which, in its scope and bearing upon this vexed question of electric circuit protection, is entitled to be called authoritative. I refer to Mr. McDevitt's report to the Philadelphia Board of Fire Underwriters, entitled: "The Gross Untrustworthiness of Fuse Metals and Appliances as a Means of Protection for Electric Circuits."

The recent paper read by Professor Stine, of Armour Institute, Chicago, before the American Institute of Electrical Engineers, entitled "The Rating and Behavior of Fuse Metals," unqualifiedly condemns present methods and practices. The meeting last week of the various electrical interests, in New York, to discuss the rules of Boards of Fire Underwriters, discussed the question of the proper protection of electric circuits, in a manner which would lead a layman to think that the present methods of electric-circuit protection were wofully at fault.

A report of a committee of the German Union of Electricians, recently published, declares that no satisfactory results were reached concerning standards of lead-strip

fuses, and offers a prize of $75 for the best solution of the problem. Up to this time no one has been able to claim the prize, and we feel sure that a standard can never be realised because of the inherent faults in fuse metals.

The theoretical considerations involved in fuse-metal practice are simple, and by reason of this simplicity the grave underlying *practical* faults are overshadowed and lost sight of by those who should lead and guide in the questions entering into the use of electric-circuit-protecting devices. That this element of theoretical simplicity has influenced the opinions of those of high scientific standing is very pertinently expressed by Prof. F. B. Crocker, in his discussion of Professor Stine's paper above mentioned. Professor Crocker says: "This paper, while dealing with a question that is by no means new, and should long ago have ceased to be a subject of discussion, is, nevertheless, one which is more constantly discussed and no more settled than many of the problems which are inherently far more difficult."

The physical conditions governing the fusion of a wire would appear to be very definite and easily determined; but the fact remains that to-day fuse wires are not to be relied upon, and the very term "fuse wire" is almost synonymous with unreliability.

Preece, of England, established the law that

$$C = ad^{\frac{3}{2}}$$

wherein

C = fusing current in ampères,

d = diameter of wire in inches,

a = constant depending upon the metal.

This law is concise, simple and readily understood. Constants (a) have been determined, and to all intents and purposes the whole subject of fuse metals is settled. It is here that practical knowledge of the actual conditions have been overlooked. Until recently the cry has been to adopt one particular fuse metal and certain specified sizes and dimensions of fuse blocks for different ampèrages, as it is claimed

that standards such as this will overcome the objections heretofore raised, and that our troubles will be at an end.

It is here that the writer wishes to emphasise the fact—the practical fact—that fuse metals cannot be considered as the correct and safe means for protecting electric circuits.

Let us define what a fuse is. A fuse depends for its action upon the heating quality of the current. Time and current combined melt fuses. A fuse does not operate the instant that C becomes excessive, but does so when C^2t becomes excessive. (C stands for current in ampères, t for time in seconds.) A fuse is placed in a circuit as a protection against some unforeseen accidental condition. Unfortunately, an accident is an occurrence over which we have no control, and a short-circuit, or maximum abnormal condition, is as likely to arise as a mere overloaded condition. The facts are that, in practice, short-circuits, crosses and grounds occur almost exclusively, and the very condition under which fuses are designed and intended to act is not present, to wit: *time* and *current*. The current rises very high, far in excess of the rating and capacity of the fuse and of the circuit the fuse is to protect. It is the occurrence of the short-circuits which upsets the theories, as the fuse is intended to meet only a slightly overloaded condition of circuit.

In a screed recently published by a prominent fuse wire company, the requirement, as above outlined, of a long-continued, slightly overloaded condition of circuit (allowing sufficient time to elapse to heat the fuse metal to melting point) is very clearly expressed. Further, in order to emphasise the fact, the fuse wire company states expressly that, for any condition of circuit other than the above, a fuse is not adapted, and some other device, wherein magnetism is the medium to open the circuit, must be employed.

It is interesting to note the manner in which this popular misconception of the practical behavior of fuse metals has evidenced itself, and still more interesting is the fact that the very thing devised has not been adopted or applied in practice. I refer to magazine fuse blocks. There have been issued some twenty-seven patents upon forms of fuse blocks

to renew fuses automatically. The reason magazine fuse blocks have not been adopted is due solely to the fact that, when circuits are opened by fuses "blowing" or "fusing," it is usually due to some short-circuited condition or other cause, such that attention is required upon the part of the operator, or person in charge, to seek for and remove the defect.

We will now consider in detail, and, by a few tests, demonstrate some of the inherent defects in fuse metals which condemn them as a safe and reliable means for protecting electric circuits from unusual and abnormal conditions.

First.—Fuses carry 50 to 200 per cent. current in excess of rated fusing current.

A 20-ampère fuse wire in a commercial fuse block permitted the passage of 50 ampères for five minutes. Upon the fuse "blowing," an arc was maintained until broken at switchboard by opening the circuit.

Second.—Under short-circuits, a fuse will carry excessively abnormal currents.

The following tests illustrate clearly how armatures in dynamos have developed in their insulation, owing to the mechanical stresses thrown upon the insulation upon the occurrence of short circuits. The arcing attendant upon a short-circuit does more damage for the time it acts than almost any other accompanying circumstance. The importance of opening the circuit in the shortest possible time after a fault occurs is apparent.

TESTS.

(1) Upon making a short circuit through a 5-ampère fuse wire, a magnetic circuit-breaker, in series with the fuse, was opened, although the circuit-breaker was adjusted to open upon 250 ampères.

(2) Similar test with a plug type of fuse of 10-light capacity opened the main magnetic circuit-breaker, set to open on 350 ampères.

(3) Similar test with a No. 30 B. & S. gauge copper wire opened the magnetic circuit-breaker set at 200 ampères.

(4) Grounding a gas-pipe and touching the gas-pipe with a wire connected to other side of the circuit, protected by a 20-ampère fuse, with a resistance in circuit such that not over 30 ampères could flow, caused a vicious arc, burning through the iron pipe, and ignited the gas. The same test performed with a magnetic circuit-breaker, in circuit set at 25 ampères, opened every time with no damage to pipe.

(5) A flexible cord was chafed and the wire strands were touching, causing a short-circuited condition, which is common in practice. Upon closing main switch, a short circuit occurred, resulting in firing or igniting the insulation, and the combustion of the cord.

Third.—Commercial fuse metals made of alloys, so as to have a low melting point, will "maintain" at a red heat.

The fire risk here is quite apparent, as the temperature is such that the metal is liable to ignite combustible material and set a building on fire.

Fourth.—The metals—copper, aluminum, iron, etc.—are not adapted for fuse metals, owing to the high temperatures required for fusing.

Melting points of metals are, in degrees F., as follows:

	Degrees F.
Antimony	880
Bismuth	512
Brass—cast	1,760
Copper	2,000
Iron	2,100
Lead	620
Tin	450
Zinc	780

By some the use of copper as a fuse metal has been unwisely urged. There is, of course, one very strong argument in its favor. For a given carrying capacity of copper, compared to metal such as lead and tin of a lower melting temperature, the cross section is much less, and, in the event of the fuse "blowing," there is, of course, much less metal to be disrupted and make current-carrying gases. However, the feature of "maintaining" at a red heat condemns high-melting point metals as fuse metals.

Owing to such metals being maintained at times at a

temperature which causes oxidation and molecular changes, the life and characteristics of the metals are materially affected, thus introducing an additional uncertainty. Captain Brophy, Electrical Engineer with the State Commissioner of Wires of Massachusetts, has repeatedly stated, as the result of his experience of many years as an electrical inspector, that, "as fuse metals age, I find that their carrying capacity increases very rapidly."

Fifth.—Fuse metals cause arcing upon "blowing."

As stated before, if fuse metals would always blow under slight overload conditions for which they are designed, the time element of arcing upon "blowing" would not be much of an objection, though, of course, arcing with simple continued overload conditions does occur at times, and introduces a serious fire risk, as described by Mr. William McDevitt, in his paper above mentioned.

The real danger, however, consists in the arcing following the "blowing" of a large fuse in event of a short circuit. (Fortunately for the electrical profession at large, it very rarely occurs that the large-capacity fuses blow. Inquiries among engineers and contractors, as to whether they recall having large fuses blow, have invariably elicited a negative reply.) This is due, as is now understood, to the fact that C^2t is such a large quantity, and t is so short that C^2 on the smaller fuses or points of break burns itself out; or, as was recently the case in Philadelphia, upon the occurrence of a short-circuit, a fuse carried current without blowing, and wrecked the dynamos and engine.

In power transmission and central station work, when fuses have been known to blow under short-circuited conditions, much of the damage done the fuse terminals and surrounding insulation was due to the severe, vicious arcing, maintained, of course, at the expense of the terminals.

Sixth.—Enclosing a fuse is not safe, as the gases generated upon the fusion of the metal will continue to carry the current in the event of a short-circuit.

Arcing is a necessary evil; any effort to abolish it will be followed by disruptive E.M.F.'s and breaking down of insulation. Since arcing is present, let us reduce its destructive

effects to a minimum. An arc is a flexible floating conductor; enclosing it in anywise makes it more dense, and its carrying capacity is thus materially increased. Practical test has demonstrated conclusively the importance of using as short a fuse as possible, in order to reduce to a minimum the formation of gas—the longer the fuse, the more metal to fuse and form gas. Further, the terminals should be so protected as to reduce to a minimum the formation of gas and arcing after the circuit is free from the first disruptive induced electromotive forces present upon the first opening of the circuit. Let the fuse blow or vent in a fuse chamber; prepare the chamber, if you choose, so that the flame cannot get out to ignite any combustible, but provide plenty of vent for the gases.

Seventh.—Fuse metals are very sluggish in fusing.

This is a proposition which the previous tests demonstrate. The evil effects of this quality are obvious. It has been urged by those not familiar with the practical operation of magnetic circuit-breakers that they have a "hair-trigger action," and that this militates against their practical utility, owing to their tendency to open at the slightest provocation. This argument is not based upon facts, as in practice magnetic circuit-breakers are adjusted to open upon a current some 25 per cent. in excess of the maximum normal rises in current.

It is apparent, from the above tests and conclusions, that fuse metals are not a satisfactory means for protecting electric currents. The other factors of uncertainty, such as shape, position, length, temperature, alloy, Peltier effect, expansion and contraction, terminals, effect of current flow, etc., have not been considered, as they are now pretty well understood.

If simple slightly overloaded conditions are all that fuses are to guard against, then fuse metals properly made and rated are probably a better protection than none at all; but, under actual conditions in practice, for circuits over 10 ampères capacity, it is very poor engineering practice to use fuse metals.

It might be interesting to know that some electrical en-

gineers of the highest standing have abandoned the use of fuse metals on circuits of large capacity.

After an arraignment, showing the absolute worthlessness of a device so long established as the fuse, it is pertinent here to refer to the device which is supplanting it. I refer to the magnetic circuit-breaker, an apparatus that automatically opens an electric circuit through the medium of the magnetic quality of the current. Since the magnetic action of the current is simultaneous with the flow of current, the time of opening is dependent, then, upon the mechanical means set into operation by the magnetic action of the current flow.

The method usually employed to effect this opening is as follows: An armature of an electro-magnet moves upon the flow of a predetermined current, tripping a catch which permits a spring to throw out a switch. The features in this construction alone are faulty, owing to the constant time required to open the circuit, which, in the event of a short-circuit, allows the current to assume enormous proportions. The proper construction of a magnetic circuit-breaker should be such that, as the conditions in the circuit to be protected become more and more severe, the device shall automatically open more and more quickly. This feature of an inverse time element is incorporated in the devices before you, the action of which is as follows: The plunger moves up and trips a catch, and continues upward and imparts its acquired energy to aid in wiping or throwing out the switch arm. Under severe overload conditions, a point or flow of current can be reached when the velocity of the plunger with its acquired energy is greater than the compressed spring, resulting in the opening of the switch in a manner independently of the spring.

The following test was made to illustrate this construction: A 12-ampère I-T-E magnetic circuit breaker was taken, and the spring used to aid in throwing out the switch was removed. Upon closing the circuit the plunger moved up with such a velocity that the switch was thrown out by the impact. This feature is certainly very interesting, as it exemplifies in practice the conditions established by Helm-

holtz' law for sudden changes in the condition of a circuit, to wit:

$$C = \frac{E}{R}\left(1 - e^{-\frac{Rt}{L}}\right)$$

C = Current in ampères.

E = Applied electromotive force.

R = Ohmic resistance of circuit.

E = Naperian base of logarithms.

L = Coefficient of self-induction in henrys.

t = Time of opening circuit in seconds.

This law shows mathematically that the more quickly a circuit can be opened the less will be the resulting flow of current. Further, the quicker the switch leaves its contacts, the less the arcing effect, as the current is given less time to heat up the final leaving points.

The following are the salient features entering into the correct design of magnetic circuit-breakers:

(1) The magnetic circuit-breaker must have the feature of opening the circuit in progressively less time as the conditions of the protected circuit approach a short-circuit; that is, it must have an inverse time element. The electro-magnetic part of circuit-breakers must be designed to develop more energy than is necessary to trip the retaining catch. The additional energy developed must be applied directly to aid in opening the switch.

(2) A magnetic circuit-breaker must have no springs in its adjustment.

(3) Insulation must not enter into the construction of the trigger or catch.

(4) All bearing pins and parts liable to be affected by corrosion or rust must be of phosphor-bronze, and moving iron parts must be copper-plated.

(5) The armature, or plunger, of the magnetic circuit breaker must not act on the retaining catch or switch arm unless a free preliminary movement precedes such action.

NOTES AND COMMENTS.*

ACETYLENE AND INSURANCE.

At a recent meeting of the Philadelphia Fire Underwriters' Association, Mr. Chas. A. Hexamer gave his views on acetylene gas, viewed from the insurance standpoint:

"Acetylene gas burns with an exceedingly luminous flame of much greater candle-power than the best city gas. If furnished to the consumer through underground pipes in a manner similar to the present system of city gas supply, there would be no greater risk from its use than from the use of city gas. In order to cheapen its use, however, it is proposed to supply acetylene gas to the consumer in cylinders, in a liquefied state, under a pressure variously estimated at 750 to 1,000 pounds. It is stated that a cylinder of gas, 4 inches in diameter, 4 feet high, will contain enough gas in a liquefied state to supply an ordinary ten-room dwelling with gas for three months. These cylinders it is proposed to connect directly with the gas pipe in a building; when empty, to be disconnected and a new cylinder substituted. It is necessary to reduce the 1,000 pounds pressure in the cylinder to a small fraction of a pound at the burners. This is done by a Pintsch valve, a rather complicated mechanism.

"Two important questions present themselves at this point:

"(1) What would be the result if a possible fire in the building should reach the acetylene cylinder?

"(2) What would be the result if the reducing valve failed and the entire gas pressure in the cylinder were suddenly thrown into the gas pipes in the building?

"It is stated that, while it is true that an increase of temperature involving the gas cylinder would produce increased pressure, before the pressure would cause a rupture of the cylinder (which is said to be tested to 3,000 pounds) decomposition of the acetylene gas into carbon and hydrogen would result, with no explosive effect. This result, it is claimed, has been obtained by heating a small cylinder of liquefied gas in a fire to a cherry-red heat. While this may be true (and similar decomposition of gases—notably hydrogen sulphide, which in a cylinder subjected to heat deposits free sulphur and liberates hydrogen—are known), it remains to be demonstrated whether cylinders of liquefied acetylene gas can safely be heated without disastrous results, the fact being that the quantity of hydrogen liberated equals in volume the acetylene decomposed; the danger of a rupture of the cylinder, therefore, is not eliminated by the decomposition of the acetylene. The result of failure of the reducing valve, which operates automatically, can be easily imagined. The liberating of a gas at nearly 1,000 pounds pressure into gas

* From the Secretary's monthly reports.

pipes not intended to carry more than a few pounds pressure must necessarily produce disastrous results.

"From the above it will be seen that the points of interest to the underwriter are the presence of cylinders of liquefied gas in buildings in case of fire, and possible failure of the valve intended to reduce and regulate the slight pressure of gas necessary at the burner. There is no reason why the objection from these points should not be overcome. Cylinders of compressed gas can and should be located outside the building, and a safety valve can be provided to empty the cylinder, discharging the gas into the open air outside of the building, in case the reducing value fails to act.

"Besides furnishing acetylene in liquefied state under pressure, it is proposed to introduce small gas machines intended to generate acetylene directly from the calcium carbide. Apparently no special hazard attaches to this plan, provided the gas machine be located outside the building, and provided the calcium carbide be stored in a dry place and free from an accidental contact with water, which, generating the gas, might cause a fire or an explosion by coming in contact with an open light.

"It is too early to formulate rules and requirements for safe introduction of acetylene gas for illuminating purposes. The subject has hardly passed the experimental stage. The result of an accident to a cylinder of the compressed gas brought it forcibly to the attention of the underwriter. That the disaster was the result of the accidental and possibly careless breaking of a valve being experimented with cannot be allowed to modify the deduction to be drawn. As an illuminant, acetylene is so far superior to ordinary city gas that, if the claim made as to the relative cheapness of its production can be substantiated, its general introduction may be expected. A careful consideration of the subject by underwriters' associations is necessary. In the meantime, underwriters are wise who carefully consider each application for the use of this new gas in its present state of development, and, until proper regulations and requirements have been formulated for its safe introduction, refuse to grant permission for its use in buildings covered by their policies."

MECHANICAL FLIGHT SUCCESSFULLY ACCOMPLISHED BY PROFESSOR LANGLEY.

It has been an open secret that the eminent physicist who occupies the post of Resident Secretary to the Smithsonian Institution, has, for a number of years, been quietly prosecuting investigations into the problem of artificial flight, and, from time to time, the newspaper press has contained notices of his progress towards its solution. The latest publication on this subject contains the highly interesting announcement of the successful flight of a model machine constructed on his plans.

While no details are given of the construction and operative mechanism, the facts of this remarkable performance, vouched for, as they are, by so competent an eye-witness as Professor Bell, are important enough to place

on record, if, indeed, they do not mark the beginning of a new epoch in the history of mechanical flight.

Prof. Alexander Bell, who was associated with Professor Langley in the test recently made public, describes the successful experiments, which were carried out near Occoquan, Va., on May 6th, as follows:

"Last Wednesday, May 6th, I witnessed a very remarkable experiment with Professor Langley's aerodrome on the Potomac River. Indeed, it seemed to me that the experiment was of such historical importance that it should be made public.

"I should not feel at liberty to give an account of all the details, but the main facts I have Professor Langley's consent for giving you, and they are as follows:

"The aerodrome, or 'flying machine,' in question was of steel, driven by a steam engine. It resembled an enormous bird, soaring in the air with extreme regularity in large curves, sweeping steadily upward in a spiral path, the spirals with a diameter of perhaps 100 yards, until it reached a height of about 100 feet in the air, at the end of a course of about a half mile, when the steam gave out and the propellers which had moved it stopped.

"Then, to my further surprise, the whole, instead of tumbling down, settled as slowly and gracefully as it is possible for any bird to do, touched the water without any damage and was immediately picked out and ready to be tried again.

"A second trial was like the first, except that the machine went in a different direction, moving in one continuous gentle ascent as it swung around in circles like a great soaring bird. At one time it seemed to be in danger, as its course carried it over a neighboring wooded promontory, but apprehension was immediately allayed as it passed 25 or 30 feet above the tops of the highest trees there, and, ascending still further, its steam finally gave out again, and it settled into the waters of the river, not quite a quarter of a mile from the point at which it arose.

"No one could have witnessed these experiments without being convinced that the practicability of mechanical flight had been demonstrated.

"ALEXANDER GRAHAM BELL."

Professor Langley supplements the foregoing by the following statement, giving some important data regarding the recent experiments:

"The aerodrome, or flying machine, has no gas to lift it, as in the case of a balloon, but, on the contrary, is about 1,000 times heavier, bulk for bulk, than the air on which it is made to run, and which sustains it somewhat in the way in which thin ice supports a swift skater.

"The power is derived from a steam engine through the means of propellers, but owing to the scale on which the actual aerodrome is built, there has been no condensing apparatus to use the water over and over. Enough can be carried for only a very brief flight, a difficulty which does not belong to larger machines than the present example, in which the supporting surfaces are but about 14 feet from tip to tip.

"The distance flown each time was about one-half mile. The rate of

speed depends (as in the case of any vehicle on land) on whether it is going on a level or uphill. In the case of this last trial of May 6th, the machine was ascending, that is to say, it was going uphill all the time, and went through a distance of one-half mile or more in one and one-half minutes, or at the rate of a little more than twenty miles an hour."

CALCIUM CARBIDE AND ACETYLENE.

The following abstract of the report of Messrs. Houston, Kennelly and Kinnicutt, the experts commissioned by the *Progressive Age* to investigate and report on the Willson process, as operated at Spray, N. C., is quoted from the *Electrical World:*

The report of Houston, Kennelly and Kinnicutt was made to settle the question of cost of the material. They visited the works of the Willson Aluminum Company, at Spray, N. C., and made an examination and test of the process of manufacture of calcium carbide, as it is there carried on. The report is given in all its details, only a few of which can be given here. A description of the plant is given; it includes two alternators of 120 kilowatts, operating at a voltage of 1,155, the currents being transformed down to about 100 volts for furnaces. In the very carefully made tests two complete runs were made in the same furnace on two different days; in the first one, 1,200 pounds of lime and 800 pounds of coke were placed in the mixer, and thence in the furnace for three hours; the mean primary current was 156 ampères at 1,000 volts; the charge which was taken out consisted of 226·5 pounds of gross calcium carbide and 1,332 pounds of mixture unacted upon; the second run was somewhat shorter, namely, two hours and forty minutes, and contained about the same charge, the resulting material being 203 pounds gross calcium carbide; the mean power was 205·6 horse-power at the transformers, and 195·3 at the furnace; the average yield of the net calcium carbide was 5·09 cubic feet of acetylene per pound. A detailed table of the yield of calcium carbide in these test runs is given; in this it is stated that the pounds of gross carbide per furnace horse-power hour averaged 0·3905, and the net carbide 0·3723. The methods and results of the chemical analysis are given. This is followed by a detailed estimate of the cost, the concluding figures of which are as follows: Cost of plant, $11,955; labor, $11; materials, $14.39; these, together with power ($3.37), interest, depreciation, etc., amounted to $32.767; this is based on an output of gross carbide of 2,000 pounds per twenty-four hours; the freight charges on lime and coke are very heavy at Spray, and add materially to the cost. The net carbide gave an average yield of 4·926 cubic feet of acetylene gas per pound; pure calcium carbide should yield theoretically about 6, so that the net carbide averaged 82·1 per cent. of the theoretical yield. This report is followed by a supplementary one by Messrs. Houston and Kennelly, in which they give an estimate of the cost of manufacture on a more extended scale, and at a locality where the materials would be less expensive; they assume a plant having an output of 5 short tons of the

gross material per day, and operating 300 days a year by water-power, which latter costs $5 per horse-power per year; the investment will be $44,700, the labor $7,550; insurance, taxes, interest, depreciation, oil, etc., $5,575; water-power and rent, at the rate of 1,200 horse-power, $6,000; materials, $10,937, making a total of $30,062 per year for 2,500 short tons of gross carbide, which amounts to $20·040 as the cost for 1 short ton. General equations are deduced for calculating the cost under different conditions; in a perfect furnace and if the line costs $2.50 per short ton, coke $2 75 and an electrical horse-power $12 at the furnace, the limiting cost of the carbide would be $8,734 per short ton; owing to the impurities of the materials, and as the furnace is not theoretically perfect, the minimum value would be $14.97; under favorable conditions, which can be realised in peculiar localities, the total cost per short ton in a plant producing 5 tons a day might be $20.

TESLA'S NEW LIGHT.

The *Public Ledger*, of May 21st, contains the following interesting item of news:

It is announced that Nikola Tesla has solved the problem which he set before himself many years ago, and which may revolutionise the system of electric lighting. It is, electrical experts say, the nearest perfect adaptation of the great force of nature to the use of man.

In Mr. Tesla's laboratory in Houston Street, is a bulb not more than 3 inches in length, which, when the current is turned into it, becomes a bulb of light. The mat is almost imperceptible. With it a very large room is so lighted that it is possible to read in any corner. Yet this is done without the attachments necessary in existing lights.

The rays are so strong that the sharpest photographs may be taken by them. No new dynamo is required to produce the current. There is no danger of harmful shock in its use.

Stories have come from time to time from Mr. Tesla's laboratory that he was experimenting on a light of this sort. Rumors of success and failure have followed each other, and Mr. Tesla's friends were inclined to doubt that he would succeed. A half-dozen times the discovery was at his finger tips, only to elude him. But now he has told his friends of his success.

Mr. Tesla has been working for many years on his theory of the necessity and practicability of the conversion of electricity. The present incandescent light gives only 3 per cent. of illuminating power; the other 97 per cent. is wasted in heat.

In accordance with his theories, which have been already applied successfully to the economical transmission of the electric fluid, he applied himself to the saving of some of this wasted energy in electric light.

The bulb which he has perfected gives 10 per cent. of light and loses 90 per cent. of energy. Mr. Tesla declares that he will, with the aid of a few more experiments, be able to produce 40 per cent. of light, so that the waste will be reduced to only 60 per cent., or 37 per cent. less than at present.

The principle of the light is vibration. The illumination is secured by means of what Mr. Tesla terms a vibrator within a bulb, which holds the vibrating needle within a vacuum. The needle vibrates so rapidly that the figures per second sound imaginary, but it is this intensity of energy which gives the light its brilliancy and its apparent steadiness. The lights do not have to be renewed.

REMOVING RESTRICTIONS FROM THE FRENCH UNIVERSITIES.

It will be of interest to American students desiring to avail themselves of the advantages of the French higher schools, to learn that the Conseil Supérieur de l'Instruction Publique, of France, has issued a decree which removes the restrictions imposed on American and other foreign students in French universities and gives them a status similar to that accorded them by the German universities. The memorial addressed to the Conseil by Prof. H. J. Furber, of the University of Chicago, called attention to the fact that there were only 30 students at the Sorbonne, while there were 200 at the University of Berlin. The conditions will now probably be substantially changed by the new decree.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, May 20, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 20, 1896.

JOS. M. WILSON, President, in the chair.

Present, 208 members and visitors.

Additions to membership since last report, 5.

The Secretary presented and read a communication from Mr. A. v. Kerpely, the President of the Executive Committee of the Mining and Geological Millenial Congress, to be held in Buda-Pesth, September 25–26, 1896, in connection with the commemoration of the Millenial Anniversary of the foundation of the Hungarian kingdom.

The President was authorised, by vote, to use his discretion in naming a delegate to represent the Institute at this Congress.

Mr. Richard W. Barkley, of New York, gave an account of the process of Professor Joly, of Dublin, of reproducing the colors of nature by photography, and showed a number of lantern slides illustrating the process. The meeting passed a vote of thanks to Mr. Barkley for his interesting communication.

Mr. Arthur Kitson presented an illustrated paper on the Kitson gas producer.

Prof. Arthur W. Goodspeed, University of Pennsylvania, by special invitation, exhibited a number of lantern slides of Röntgen radiographs, made by himself, which illustrated in a remarkable manner the great advances that had been made in this newly-opened field of investigation, since its first announcement, about six months ago.

The speaker was accorded the thanks of the meeting.

The Secretary exhibited and commented on some new cellulose products made by Messrs. Cross, Bevan and Beadle, of London, and the product known as steel wool, of which specimens were shown.

On motion of Mr. G. M. Eldridge, the following preamble and resolutions were adopted without dissent, viz.:

WHEREAS, The Act of Congress of the United States in force prior to January, 1895, provided for the distribution of the monthly volumes of patents to such libraries as would pay for the binding thereof and comply with certain regulations relating thereto; and

WHEREAS, The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, has and various other public libraries have complied with said regulations and paid for binding, and have received and have now on their shelves all such monthly volumes up to and including the month of December, 1893, to the great accommodation and advantage of the public seeking information regarding patents; and

WHEREAS, On the 12th of January, 1895, an Act of Congress was passed inhibiting such distribution of these volumes, whereby great inconvenience has resulted to such seekers for information; and

WHEREAS, The presence and use of these monthly volumes of patents is of great service to the general public, but of no profit or advantage to the Franklin Institute or to such other libraries or to its or their members, beyond other persons;

Be it resolved, By the Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, that the Congress of the United States be and hereby is respectfully petitioned to take such action as will restore the privileges of distribution of such monthly volumes of patents to the condition in which it existed prior to the passage of the Act of January 12, 1895;

And be it further resolved, That the Congress of the United States be and hereby is respectfully petitioned to take such action as will class the bound monthly volumes of patents with other publications of the United States, so that they may be distributed, like such other publications, to libraries which are designated as depositories of public documents, as heretofore and now provided by law in relation to such other publications.

Adjourned.

WM. H. WAHL, *Secretary*.